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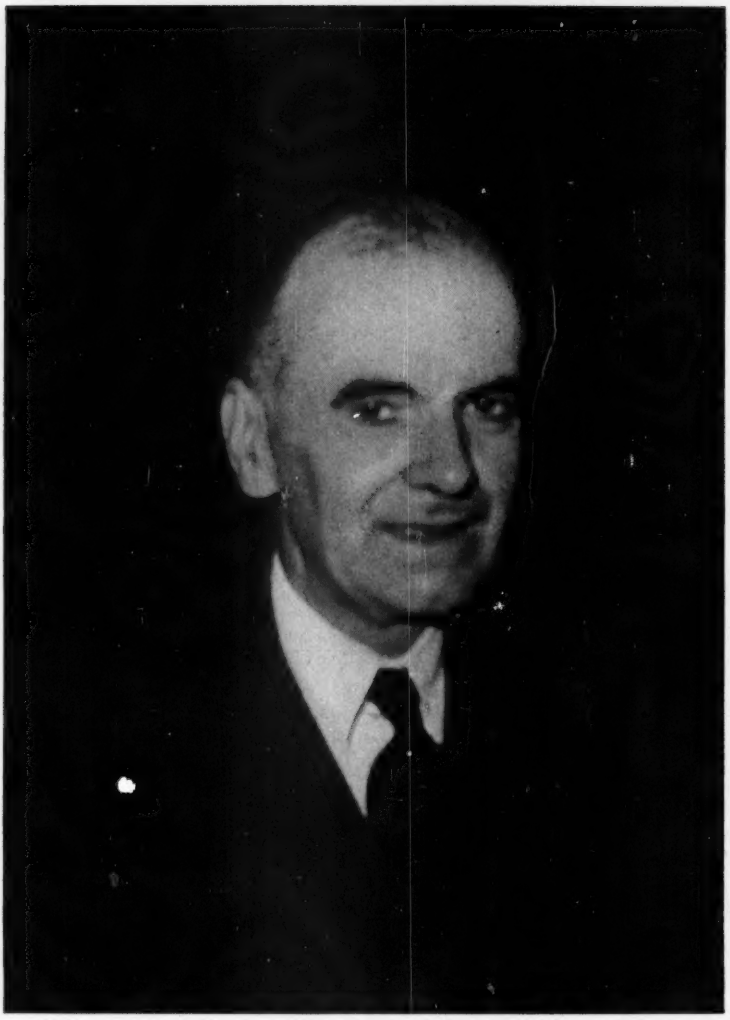


Professor F. H. GARNER, O.B.E., M.Sc., Ph.D., M.I.Mech.E., M.I.Chem.E., F.R.I.C.

REDWOOD MEDALLIST, 1951

[*To face p.* 663.

THE INSTITUTE OF PETROLEUM

REDWOOD LECTURE

A Meeting of the Institute of Petroleum was held at Manson House, Portland Place, W.1, on October 3, 1951, when Professor F. H. Garner, O.B.E., delivered the Redwood Lecture and was presented with the Redwood Medal. Mr M. A. L. Banks, vice-president, was in the Chair.

Opening the meeting the Chairman said :—

The occasion of the delivery of the Redwood Lecture and the presentation of the Redwood Medal is always an important occasion in the proceedings of the Institute, and we are all delighted to-day to see Professor F. H. Garner with us. I shall have an opportunity of expanding on this theme later, but first I must apologize to Professor Garner for the absence of the President, who should be in the Chair to-night. Unfortunately Mr Southwell has been called away to Kuwait on an urgent visit.

Professor Garner has chosen as the subject for his Redwood Lecture "The Training of a Technologist." I really cannot imagine a more interesting subject at the present time when an enormous refinery expansion is under way in the United Kingdom, but I would venture to suggest that the subject is not only interesting, but is in fact, extremely important, not to say, vital.

Unless the implications of this subject are properly appreciated right through the country, namely what the right education, development, and working of the young technologists can mean to our industry, the standard of living in the United Kingdom must continue to deteriorate.

Professor F. H. Garner, O.B.E., who was received with applause, then delivered the Redwood Lecture which follows :—

THE TRAINING OF A TECHNOLOGIST

By Professor F. H. Garner, O.B.E., Past President

It would be generally agreed amongst scientists, both pure and applied, that their training should include an all-round education and that ignorance of history, of literature, and of art implies a lack of understanding of the human mind. On the other hand, amongst the humanists it is by no means accepted that some knowledge of science is essential in understanding the human mind and the world in which we live to-day; we can no longer agree with the statement "What broader education could a boy have if he does both Latin and Greek?" A man trained in the humanities only, without a knowledge of scientific methods and achievements, suffers a serious impoverishment in his whole intellectual life. In addition, the applied scientist—the technologist—must have special personal qualities of leadership and must know how to handle men, and this leadership can be gained by personal contact rather than through books.

The term "technologist" is unsatisfactory, but has generally come to mean scientists who have studied the application of the results of scientific knowledge and discovery to industries and arts. These include professional engineers whose education is primarily scientific, since to translate the results of laboratory research into manufacture requires a thorough knowledge of the fundamentals of the appropriate related sciences and particularly physics, mathematics, and chemistry. The technician, on the other hand, is one skilled in the mechanical part of an art, and his training is the primary responsibility of the technical college. It has been said that education is a process of teaching which produces an attitude of mind and that training is that which produces an aptitude of mind, but in this lecture it is preferred to consider training and education as synonymous, as there is no evidence that Anglo-Saxon training was in any way inferior to Norman education.

In a discussion of the training of the applied scientist, reference should be made to the feeling that recent developments in science have endangered the whole future of mankind and that this is in some ways connected with a deficiency in the training and outlook of scientists. The results of scientific discovery can be applied well or ill, and it is the standards of intelligence and moral standards of the whole of the educated communities, not those of the scientists alone, which are responsible for the decisions. However, it is significant that until the last fifty years or so the whole of our educational system has been inspired and conducted by those trained in the humanities, that is, in the principal systems of moral philosophy which have been practically operative amongst mankind. Yet the result of such training through hundreds of years is now said to be that the educated section of the community is unfitted to deal with the problems facing us to-day and lacking in a clear and worthy way of life.

That a training solely in the humanities leads to a wider vision has been stated frequently and forcibly by men with such a training, some of whom occupy positions of authority. Their point of view has been discussed by Newman in his "Idea of a University" (in "Rise and Progress of Universities") with which most people find themselves at least partly in agreement. Newman described the university as a school of universal learning, and he described books, *litera scripta*, as one special instrument, but the detail, the colour, the tone, the air, the life which makes it live, all these must be caught from those in whom it lives already. Although Newman does mention the university as a place in which inquiry is pushed forward and discoveries verified and perfected, this is only a minor part of his idea of the university where the establishments of literature and science should be in subordination to ecclesiastical authority.

Lord Cherwell says, "It is difficult to see why a man should be said to have enjoyed a liberal education if he knows something about the classics and very little about science and engineering, whereas he is reviled as a mere technologist if he knows about science and engineering and very little about classics. Merely because one brand of learning was the more important in the sixteenth century does not prove it to be superior to other branches which lie at the root of all our production in the modern world."

The argument in favour of an education largely or wholly based on humanities relies to a great extent on the part that such an education has played in

our traditions and in our national character and in the outstanding contributions we have made to the civilization of the whole world. On the other hand, humanists in general appear to be in some doubt whether at the present time there has not been a decline in the character of the man turned out by our universities. Part of this is due to the feeling that our international standing has fallen, and the great expansion of the empire in the later periods of the Victorian era, followed by its subsequent contraction, has played an important part in this feeling. The policy which has been followed, and our foreign policy in general, is largely the policy of men trained in the classical tradition, and there appears to be evidence of something lacking in the training of such men to-day; this is particularly evident in dealing with the relatively simple-minded brutality of the Russian communistic world, possibly because its code of behaviour is different from our own.

Is it, however, true that the most important change in the character of our education has been the replacement of the classical by scientific education? It would appear that a far more potent change has been that towards religion, which for so many generations permeated our national life. This intensity of religious feelings has been particularly strong since the Reformation, and religion played a great part in the lives of all scientists at the inception of modern science in the seventeenth century, as is evident by Boyle and Newton. This continued till the late Victorian and Edwardian eras, when the Epicurean cult of leisure and good living caused the decline of the appeal of religion. There has been no corresponding philosophy to replace it and to provide the element of self-sacrifice for the common good so inherently part of the Christian ideals; these ideals were widespread in a way which classical philosophies never attained.

The traditions which are important are surely those which have been long established. A perusal of the way in which foreign travellers have viewed us through the ages will show that in the really important qualities of mind and character we have a great deal in common with the Elizabethan, with the Puritan of the seventeenth century, and with the almost equally religious cavalier of the same period. It is changes in the beliefs of the people which would appear to be of primary importance and not increasing attention to science or decline in attention to the classics. Until recently religious knowledge has been the keystone of our education. There has been a violent change in our traditional beliefs, and it always appears to be important with such beliefs, not that they should not be changed throughout the years, but that the rate of any change should be slow.

The Technologist in the University

Humanities must represent a large proportion of school studies, but the qualifications for university entrance have a marked influence on the training in the humanities given at school, particularly in the later years. Sir Richard Livingstone has said that Oxford and Cambridge, with their highly specialized scholarships, are the worst offenders, as they tend to dominate the scholars and cause the excessive specialization present in all scholarship examinations.

It has been said that applied sciences are out of place in a university and that modern engineering education consists of a series of snippets of

subjects with no real grounding in any branch of science whatsoever. In the same vein, physics taught as a subsidiary degree subject might be said to be a series of snippets of light, sound, heat, electricity and magnetism, and general physics. More seriously it is said that engineers should be taught mathematics, modern physics in all its branches, and recent advances in chemistry for three years, and then learn engineering in a graduate course. This makes the wrong assumption that everything labelled mathematics, physics, and chemistry is fundamental or basic. Thus, for example, the constitution of a sugar is not more fundamental than the investigation of the flow of gas pulsations in pipes, and furthermore, is of little value to anyone but an organic chemist; both subjects are, however, equally admirable as research subjects and in training for the potential research organic chemist or research engineer respectively. As regards really *fundamental* research, there are never likely to be more than a few great scientists in each generation who make fundamental discoveries, and those few may well provide all the new knowledge required for industrial processes. The necessary development work, whether done in pure or applied science laboratories, is not *fundamental*.

In pure science, by the aid of hypotheses and logical reasoning, a coherent description is given of relationships between different *natural* phenomena, and deductions are reached which are capable of being tested by experiment. The engineer and technologist, however, are interested in the use to mankind of such deductions, but they employ the same methods in connexion with processes, machines, and mechanisms invented by Man. Thus a research school is very necessary in teaching engineering, and often the research will be of precisely the kind which the physicist or chemist might have done if he had recognized the need, but with the technologist it will always be associated with the ultimate idea of useful applications. Thus Priestley, as a pure scientist, was interested in things for themselves, but his contemporary, the engineer Watts, was interested in things for use. Both made *fundamental* discoveries.

The physicist in his training at a university will take only a small part of the mathematics taught in the mathematical department and of the chemistry taught by the chemistry department, and the part of these subjects selected has been chosen with reference to the needs in connexion with the primary subject of physics. In the subsidiary subject of chemistry he certainly will not be made acquainted with all recent advances in chemistry, and even the chemistry student is taught only a very limited selection. Nevertheless, the assumption is made that the man who is going to be an engineer should, during his three years at the university, be taught only chemistry, mathematics, or physics, a large part of which is neither fundamental nor of any value to the engineer except as a mental exercise. It is a fallacy to assume that knowledge can be allocated into boxes labelled chemistry, mathematics, or physics, when in point of fact there is an immense borderland, such as, for example, physical chemistry, which is taught in chemistry departments but might equally well be taught in physics departments. Thermodynamics, after the introductory course, has quite different emphasis placed in courses in chemistry, physics, mechanical engineering, chemical engineering, and metallurgy, but none of these is a more fundamental approach than the other.

The engineer is primarily interested in the classical physics and in the newer knowledge arising from research in this field, part of which research is done in various engineering departments in the universities. Such problems are not less worthy of serious research work than the more exciting and fashionable aspects of atomic physics. When the possibility of the release of atomic energy was first realized about five or six years ago, some eminent enthusiasts hastened to say that all the traditional methods of converting other forms of energy into useful work by the various forms of heat engines would be out of date within five years, but this prospect has gradually receded, until now it may be fifty years. This transformation is held up not by a lack of knowledge of modern physics on the part of the engineer but by lack of knowledge of techiques, of the properties of materials, and of design data.

The assumption that an engineer cannot make use of new knowledge with which he has never been fed and which he has never received would imply that the physicist is incapable of presenting his knowledge so that it can be understood by one who has had a sound elementary training in physics. Or that, in another sphere, a capable business man (perhaps solely trained in the humanities or self-educated after the age of fourteen or fifteen, is incapable of understanding new developments from his own specialist point of view—that of making profits, which should mean efficient production for the consumer at the right time and place—even when they are put forward by that paragon, an engineer or physicist who can talk plain English.

Primarily one of the main differences between the technologist and the pure scientist is that for the former it is not profitable nor practicable to study a subject thoroughly without knowing something about the possibility of putting the knowledge gained to some useful purpose. For the engineer, a knowledge of engineering drawing is just as important and just as much a proper part of his education as laboratory techniques are for the chemist or physicist.

Engineering properly taught represents a complete discipline, and produces one of the requirements of an educated man that he should have studied one subject intensively. If properly taught it can represent a philosophy, defined by Professor M. V. C. Jeffreys as the ability to see a particular field of knowledge in all its human relations, and this is combined with a belief in its function of directing the great services of power in Nature for the use and service of Man—thus ultimately meeting " one of the unalienable rights of man in the pursuit of happiness."

It should not be forgotten that human relationships are an essential element in the training of engineers, who have to deal with human problems throughout their lives. It is for this reason, amongst others, that many engineers consider it desirable that works' experience should precede entry to a degree course at a university, and should be compulsory during vacations. This contact with labour and management of industry is emphasized also in courses of tuition, as will be discussed later.

In the United States a committee of the American Society for Engineering Education has issued the following statement: " The many-sided relationship and the diverse activities of engineers have a determining influence on engineering colleges and their programmes. These institutions should not

be considered as professional schools in the exclusive sense, as are the schools of law, medicine, and theology. Rather, they constitute one of the major functional branches of the national system of higher education; the technological branch as distinct from agriculture, commerce, journalism, education, and the like. For the most part engineering colleges have given their students a sound, general education, distinctive in type and useful in a wide range of occupations. They have emphasized professional responsibilities and ideals more than other colleges of a general functional type, and this emphasis has contributed to the coherence of their work, but few have made preparation for strictly professional practice their dominating objective."

Early Ideas on Technological Training

Napoleon's accusation of " a nation of shopkeepers " must have struck us deeply, and there is a feeling that to do anything useful in life is inferior to a life of philosophic calm dispensing advice with an air of " effortless superiority " to all and sundry. This feeling is particularly marked in some educational circles, whereas the whole of our traditions intimately link trade and industry with our national life.

In Elizabethan times we find in the Lansdowne Papers carefully compiled lists of goods divided into two classes, the first of which could be imported, as they were essential to England, and the second which should not be imported, being either luxury goods which are not essential or useful goods which could be manufactured here either by processes imported from abroad or by new inventions. The introduction of processes for manufacturing the latter class of goods led to the development of the patent system in this country, culminating in the original of all patent laws in the Act passed in 1624. Later the unwise attempts of Charles I to foist politicians and royal favourites into commercial undertakings played their part in the alienation of London from his side and in the interest developed in manufacture and in the promotion of trade in the Commonwealth period. It was during this period that the forerunner of the Royal Society took shape, the main motives being the desire for experiments to increase knowledge and for the use of such knowledge to increase trade and improve manufactures. The intention was the encouragement of training and research in both pure science and technology.

If we go back to the seventeenth century, when the modern scientific spirit was beginning, we shall find that even then training solely in the classics was subject to criticism. Thus John Webster (described by Bush in the " Oxford English Literature " as hard headed, and, rather fatuously, by Adamson in the " Cambridge English Literature " as an obscure scribbler) in his Academiarum Examen (1654) had summed up the arguments against the view that ancient learning is the seat of all knowledge and against the neglect of the newer forms of study. He called attention to such points as a reform of the ways of learning Latin by using Comenius's picture book " Orbis Sensualium Pictus," of learning Latin and French by his " The Gate of Tongues Unlocked and Opened," and of other simpler methods of learning grammar. He recommended the use of mathematics (arithmetic) as a liberal science and one not to be relegated to merchants, masons, and carpenters (it will be remembered that Pepys, a graduate of

Cambridge who had presumably studied the quadrivium which included arithmetic and geometry, records with delight the way in which he learnt the multiplication table from a ship's mate in order that he could check the dimensions of timber sold for use in ship construction).

Webster comments on the value of training in chemistry "that youth may not be idlely trained up in notions, speculations, and verbal disputes (logical and rhetoric were part of the Trivium) but truly to be taught by manual operation, and ocular experiment, so that they may not be sayers but doers, not idle spectators—which can never come to pass unless they have Laboratories as well as Libraries." In his "Examination of Academies," Wilkins easily demolishes some of Webster's arguments, although he said that at first sight he was very much pleased with the book as being suitable to his own frequent wishes. Milton's tractate of education shows he was equally dissatisfied with the existing educational institutions, but the course of study he recommends would require a time-table which would meet with severe objections from those teachers to-day who insist on a search for the good life and not a harassed chase in the pursuit of knowledge. Cromwell had introduced Seth Ward and Wilkins to Oxford, and they were able to point out that chemistry is not *now* neglected at universities but agree that "instead of verbal exercises we should set upon experiments and observations and this is the way, and the only way, to perfect Natural Philosophy and Medicine and this way is pursued amongst us." There was also a deep-rooted desire at this period to extend the university education to centres other than Cambridge and Oxford, as for example to London, York, Bristol, Exeter, and Norwich, but this was quashed by the older universities. An even earlier attempt to found a university at Stamford in 1334 resulted in every candidate for a master's degree at Oxford till 1827 having to take an oath not to lecture at Stamford.

There was much interest in the reform of the scheme of education to provide a satisfactory basis for popular scientific educations which would have some relation to modern life. Hartlib, Comenius, and Petty were particularly active in this connexion. Harrington in "The Commonwealth of Oceana" suggested a compulsory scheme of education, free to all who could not pay for it, in schools inspected by the State and with a common syllabus of study. Petty suggested schools at which children should learn drawing, mathematics, bodily exercises, and handicrafts instead of grammar only, and this suggestion had to wait two hundred years before it was put into practice in the training of the technician. It is also important to note that the Royal Society in its early days was particularly interested in the promotion of experimental philosophy and paid much attention to trade and manufacture. Houghton, a Fellow of the Royal Society, gives us much valuable information on industrial operations in "Husbandry and Trade Improv'd." The first experiments shown to the Royal Society were engineering, not pure science—experiments on shipping, recoil of guns, experiments with the pendulum. The Royal Society itself shared objections to science similar to those voiced against the introduction of science to the university, and thus the Public Orator of Oxford, Dr Smith, raised Evelyn's anger by "his malicious and indecent reflections on the Royal Society as underminers of the university," this was in a ceremony which was followed by a speech in praise of academical learning.

Similar attempts to bring education more into line with modern thought and conditions of life continued throughout the eighteenth and early nineteenth centuries.

This element of interest in usefulness is particularly prominent in our applied arts, where our strength lies in grace of form and shape and in fitness for use rather than in applied ornament. This is true in furniture, silver ware, pottery, and porcelain. Thus, for example, a well-made stoneware beer mug with the arms of the inn and inscribed with the name of the proprietor is a beautiful object, as is a Tudor jug which stands well, handles well, and looks comely, and both of these are wholly English and this cannot be said of a Chelsea china figure, apparently much more attractive by its bright colours, but whose inspiration is foreign.

Some of the antipathy to science still remains in the common belief that a career in applied science in industry is in some way inferior in status to that in some other professions. This is often the view of school-teachers, whose training has been mainly classical, and a result there is a tendency to direct boys away from the desire to acquire knowledge for use. It is apparently considered to be of higher service to mankind to study classics or literature or to carry out so-called fundamental research than, in the words of the charter of the Institution of Civil Engineers, "to direct the great services of power in nature for the use and convenience of man." This belief is somewhat surprising in view of the fact that medical training is essentially technological training, and yet the status of the medical profession is regarded by classicists as almost on a level with their own, largely because of the long period through which such technological training has been taught in universities.

The Technologist and the Economic Position

Sir Ewart Smith has emphasized the critical importance of higher technological education in relation to the economic position of Great Britain, which depends primarily on its industrial output. The United States has taken over the dominant position once held by Great Britain, and a comparison with higher education in the United States is therefore of interest. He shows that although in about 1900 the output per head was practically equal in the two countries, output in the United States has increased by about 3 per cent per annum compared with the rate in Great Britain of almost exactly half that figure; the overall production per head in the United States is about two and one half times the corresponding figure in Great Britain. The low rate at which scientific and technological knowledge is being applied throughout industry is probably related to our inferiority in the relatively small numbers trained in applied science in Britain. Aeronautics, on the other hand, in which we are prominent, has appreciated from the outset the necessity for training and employing a very large number of first-class technologists. The proportion of the population who take higher degrees in technology in the United States is nearly the same as that for first degrees throughout the United Kingdom, and unfortunately no appreciable change is taking place in the proportion of degrees in applied science to those in pure science. Sir Ewart Smith goes on to say:

"The above broad survey, crude as it is, leads inescapably to the con-

clusion that, for a given (world) level of fundamental scientific knowledge, a major influence on the long term trend of productivity is the rate at which applied scientists are trained and used in industry.

"In an industrial country such as our own, and in a technological age, there is a clear need in all walks of life for a proper proportion of men who have had an education to university standards and particularly on the scientific and technological side.

"The traditional type of education in the classics or other arts subjects is not, *by itself*, very appropriate to the technical and managerial requirements of the present times, but we still cling to it to a far greater extent than any other industrial nation."

This same thought was put by an American educationalist more bluntly: "The standards of comparison which have been derived from Greece and the Middle Ages have long been followed in Western Europe and have conspicuously failed to solve the problems which the modern world has had deposited on its doorstep."

Much of the effort given to research in Britain is brought to fruition elsewhere because of our lack of engineers and technologists. The publication in Britain of fundamental research in this connexion is often directly relevant to applied research carried out in the rest of the world. Commercial processes are worked out elsewhere, perfected, and put into operation, and when the products are required in Britain royalties have to be paid, often on a relatively high scale, because such royalties are closely connected with the financing of applied research. It has been argued that the value of much British fundamental research is negative, since it often contributes to the development elsewhere of high-quality substitutes for natural materials such as rubber and textile fibres.

In part our difficulty is that there is a tendency to feel that graduates with arts training are more suitable for administrative posts, and graduates with applied and pure science training more suitable for technical posts, whereas too many of our administrative posts are held by people with so-called liberal education—unfortunately understood as one with no science training—whereas if the liberal education had been truly liberal and included a scientific background we should probably not be faced with our present difficulties. In addition, the large and increasing number in certain fields (particularly in the efficient petroleum industry) of administrators who were initially scientists has shown up defects of our older type of administrator and the importance of a balanced outlook.

In looking through the annual reports of manufacturing companies, there is often no mention of the products manufactured, but only reference to financial manipulations. It is refreshing in the more enlightened accounts to read of improvements in processes of manufacture of the products, of research, and of interest in the welfare of the staff. R. P. Russell has pointed out that it is absolutely necessary that those who direct research and development work, those who conduct it, and those who direct and carry out engineering manufactures and sales should have as broad and as up-to-date a picture as possible of the entire project and of the manner in which it will be handled. Continuous consultations are necessary at each operating link from top to bottom.

Sir Handley Page has said that owing to the short period of under-

graduate study, the growing specialization of science courses, and the urge to concentrate on the advancement of knowledge, with neglect or even contempt for vocational training by the university, industry does not secure enough graduates with the attitude of mind for service in the application of science. Specialization is, however, necessary in order to *know* something about the subject instead of being merely interested in it, and a wide knowledge is less important than a thorough knowledge, provided the specialization is built up to an apex from a broad basis. Thus, for example, the history of a local industry involves not only a thorough knowledge of all the scientific developments which have occurred in the building of the industry, but also of the previous history which may involve searches in the British Museum, the Public Record Office, Somerset House for wills, in the local Parish and Manor records, and into the living conditions and the methods of thought of men engaged in the industry over a period of time. Even for the true specialist with a relatively limited field we must remember that:

> He knew the signal, and stepped on with pride
> Over men's pity—
> Left play for work,
> 'Time to taste life' another would have said,
> 'Up with the curtain!'
> This man said rather 'Actual life comes next
> Patience a moment!'

And then the decision to bury the Grammarian at the mountain top where meteors shoot,

> Leave him in still loftier than the world suspects
> Living and dying.

The Graduate

And what of the product? A complaint has been made "Why are some science graduates such shocking spectacles, unable to speak or write their own language or that language crammed with technicalities which they speedily forget and incapable of ordinary thought?" [sic]. This should be compared with the following quotation from Osborn's "Advice to a Son," published in 1658, "Scholars by a too long plodding in the same track, have their *experience* seldome dilated beyond the Circle of a narrow Profession; of which they carry so apparent marks, as bewray, in all Places, by their *Words* and *Gestures*, the *Pedand Company* they were brought up in; so that all waies of preferment are stopped against them." This quotation dates from the time when a classical education was the only education, and yet apparently it did not always serve to develop character and potentiality for progress in life. On the other hand, it is not necessary to agree with the thought behind H. G. Wells in his earlier edition of the "Outline of History" in which he comments that Mr Gladstone was educated at Eton College and Christ Church, Oxford, and his mind never recovered from the process, because he was ignorant of the elementary ideas of biological science and modern political science and economic science and modern thought and literature. Sir Richard Livingstone, on the other hand, has said of chemists and physicists that "if you pass your life in the company of elements, cells, and atoms you may unconsciously be inclined to treat men as if they were cells, atoms, and elements and not human beings."

We must steer our course between these two extremes and recognize that

with an educational training in the humanities, both pure and applied science can be taught so as to enable men to be clear, logical, and objective, to be able to interest people, to weigh up various views, to reach decisions, and to explain them clearly to others, both in writing and orally.

The universities originally were largely vocational, being the training ground for the Church, and theology was still the chief subject of study in the early seventeenth century. The proportion of the population attending the universities was very large (one in 3600 of the male population attending the university, falling to less than one-fifth of this number in the leisurely eighteenth century, as against 1 in 9000 in 1911 and say one in 1800 to-day). Later in the eighteenth and for most of the nineteenth centuries the traditional form of education was primarily for a leisured section of society, and was not concerned specifically with vocational aspects. A lethargy descended on the universities in the eighteenth century, and the neglect of teaching has been attributed to the supersession of the universities by the colleges, which was broken by Parliamentary legislation in 1854. Thus the Universities of Oxford and Cambridge were brought into much closer touch with the life of the nation than since about 1650. Newman opposed this trend, and asserted the pre-eminence of teaching over research and opposed the diffusion of useful knowledge: he wished the Church to superintend the whole of activities of the universities, but did not point out that this would be in the hands of those clerics who recall Galileo's sigh Eppur si muove (se non è vero è ben trovato).

"No university of the future can escape the duty of furnishing the majority of its students with a type of training to some extent specifically related to their future career. The newer universities have tended on the whole to emphasize the vocational function of training, though this generalization is subject in many instances to important qualification. At the same time, a university would in our view fail its essential purpose if it did not contrive to combine its vocational function with the provision of a broad humanistic culture and a suitably tough intellectual discipline." ("University Development from 1935–1947," University Grants Committee, 1948.)

The Education of the Engineer

The training of a technologist of necessity requires a fuller series of lectures, tutorials, and practical classes than is necessary for arts students and these must be so directed that they lead to the development of the potentialities of the personalities of the individual students. The discussion which follows indicates some of the ways in which this can be achieved.

The branches of engineering—mechanical, civil, electrical and chemical, metallurgy, and mining—are the chief branches of technology taught at universities, but other technologies include aeronautical engineering, petroleum engineering, fuel technology, industrial fermentation, concrete technology, agricultural engineering, textiles, estate management, and a wide variety of subjects.

A thorough grasp of the appropriate sciences and their application, usually mathematics and physics with the possible addition of chemistry, is required, and it is important to avoid as far as possible the examination mentality and the concept of the university as a kind of filling station.

Before he enters the university, the student in technology should have had a good general education, particularly in the humanities, and every inducement should be employed to see that he continues progressing in his knowledge of literature, history, music and the arts, and those subjects in which he is specially interested, because as Dr Johnson said, "A man ought to read just as inclination leads him; for what he reads as a task will do him little good." He will have ample opportunity for cultivating the social side and to some extent powers of initiative and leadership in his own professional and other societies, but he should be actively interested in the other university societies and in some branch or branches of athletics, so that he breathes the same air as fellow students training in different disciplines. Halls of residence, in particular, provide the right atmosphere, but with many of the civic universities it has not been possible to provide such halls, even to a very limited extent of what they consider to be necessary. In default of this, attempts are being made to develop cultural contacts by special lecture courses and by many other schemes. It is important that the engineer should be educated in a *university* with students in other faculties and particularly with those training in the humanities.

In general, too, a personal pride in craftsmanship of some kind should be part of any educated mind, and especially for the engineer, as skill in craftsmanship is so important for the technician with whom, closely at first and perhaps more remotely later on, he will be connected for the whole of his life.

Lectures are, of course, an essential part of the course, since they convey the principles in a live manner and give opportunities of an approach to a personal contact between lecturer and students. The number, however, should be kept to a minimum and be supplemented by tutorial classes, practical classes, and seminars. For the technology student to whom his subject is particularly important since it has been chosen by him, technological information must be given, but preferably this is used to illustrate fundamental principles in the application of science. Historical information is of the utmost importance combined with reference to recent developments in order to illustrate that we are dealing with a subject in which the great engineers and scientists of the past have been seriously engaged and which is still a living problem in the minds of men.

As regards complaints concerning *factual* knowledge, it is a fallacy to assume that one can think better with fewer facts, so that some factual knowledge is particularly important in the early stages of training: to make a correct decision, the more relevant facts which are known the better. An educated man is one who can pick out the relevant facts and reach the correct decision.

Tutorial classes are of great value, in which the students in one year are preferably grouped in small numbers and problems presented and worked out under supervision; the student asks and at least partly answers the questions concerning the problem studied, or alternatively, a problem is presented and solved by each member of the whole class and then fully discussed the following week. Such classes would be in charge of a lecturer, but may be assisted by research students, for whom it presents excellent training and tends to prevent too great specialization.

The practice of requiring each student to prepare a thesis or theses on some engineering topic such as a relatively new development, or some social or economic problem, provides excellent training. Such a thesis based on a literature survey, and presented to the whole class should be finally drawn up as a report. It thus means that the student has to read for himself, weigh up the facts, and present them first orally and finally written as a well-presented, clear, logical report. This would appear to meet Bacon's " Reading maketh a full man, conference a ready man, and writing an exact man."

It is also usual in some branches of engineering to require some design problem to be worked out in the final year, and this is valuable training, since much of the design data is not available in the literature and has to be calculated from other known physical properties. In chemical engineering this design problem takes the form of mass and energy balances followed by a flow diagram accompanied with the requisite data for the material of construction and quantities required, and in addition detailed design drawings of some part of the equipment.

The university is not the place to teach the techniques of industry—that is the know-how; this must be acquired in industry but the teaching of why different techniques are used and the principles on which they are based is an appropriate course of study. Practical classes in technology will use mechanisms, machines, and techniques of testing, just as laboratory techniques are taught to physicists or analytical chemistry to chemists.

In the final year the practical classes take the form of problems rather than set pieces, and usually three or four students will be engaged together on each problem for a week or a month at a time. This gives an opportunity to make sure that every student acts as leader for a period and also provides further training in encouraging the vitally important team spirit.

The primary aim of all courses should be to stimulate the critical faculty, to teach the student to assess evidence, and to form a reasoned judgment.

The engineer must also be concerned with the economic problems in deciding whether a process or machine is practicable and thus with the relative costs of alternative schemes in both labour and money. Frequently the relationship between cost and efficiency is important, and whilst it is not practicable to give a thorough training to technologists in these subjects because of a lack of time, the student can be made aware of these problems in his classwork, in his design problems, and in lectures preferably from those engaged with these problems in industry.

Applied science cannot be adequately taught without continuous contact with industry, and this can readily be maintained in a number of ways, particularly by such lectures and by the students' vacation courses. Industry is always very helpful, and frequent visits by members of the university staff to industry and of members of industry to the university are desirable, particularly the latter, since a sense of liveness is given to research problems by their connexion with direct usefulness. The vacation courses have the advantages of bringing the student into touch not only with industrial problems but also with labour and management at a critical formative period of his career. It has been argued that it is far better to travel abroad during the vacation than take such courses—the answer to this is that the technology student often manages to do both, either

separately or together. Vacation courses abroad are, of course, of very great importance to the individual student, and through him to the whole class.

The lecturing staff in technology departments have usually had extensive industrial experience, and there is a continued exchange between universities and industries—often too much change. A further contact with industry is provided by the posts obtained by graduates in industry, usually by the particular department to which the student belongs. Since technology and engineering departments do not produce fully trained technologists or engineers, the training in industry during the first two or three years is most important, and it would be helpful if the present contacts in this aspect of training between universities and industry could be made even closer than at present, although they are the responsibility of industry. It is felt that whilst these initial years must include a great deal of know-how about factory organization, manufacture, and marketing, attempts should be made to give the graduate the greatest possible amount of responsibility so that he can have a chance to reveal his capabilities.

Graduate schools have been for long an integral part of training in United States schools of engineering, by far the largest number of which are in universities, although some are in separate institutes such as the Massachusetts Institute of Technology. It is hoped that the recent interest in such schools by the University Grants Committee will lead to their firm establishment in Britain, although at present the number of graduates in some industries is so small that it is not practicable to spare them even for one-year courses, although their cost to industry may be no more than that of two labourers. These courses of higher training should be most valuable in training men for management based on a knowledge of the products being made, of the processes being employed, of distribution problems, and last but not least of the human problems involved.

It has been said that the Roman education, with no Greek philosophy, no, or very little Greek art, no Greek dramas, was too closely connected with the practical, and hence proved fatal to the Roman Republic and that the same may happen with present so-called scientific education of to-day. After all, the same failure happened to the city states of Greece, and Athens lost first to Sparta and later to practical Rome.

Times change, and it is important to bear in mind that sciences, both pure and applied, and humanism derive from the same source, since science is but knowledge and, in the words of Cicero :

Homo multa habet instrumenta ad adipiscendam sapientiam.

PRESENTATION OF THE REDWOOD MEDAL

The CHAIRMAN : I think that my first duty should be to thank Professor Garner on your behalf for a most stimulating address. After the address comes the presentation of the Redwood Medal. Sir Boverton Redwood, whom this medal commemorates, died in 1919, and the the medal was inaugurated in 1921. That is thirty years ago. I imagine that most of us who did not have the opportunity of knowing Redwood personally think of

the name of Redwood in terms of measurement and the ability to give and to get data.

We can therefore congratulate the Awards Committee of the Institute of Petroleum on their recommendation that Professor Garner should be awarded the Redwood Medal. He is no stranger to the receipt of medals. He received an American Medal of Freedom in 1947, he is shortly due to receive the Melchett Medal of the Institute of Fuel, and recently he was awarded the Osborne Reynolds Medal of the Institution of Chemical Engineers.

Professor Garner occupies an outstanding position in the domain of oil, and I think that position really rests on three main foundations. His knowledge of the industry, his academic attainments and work, and his approach to the public-relations side.

As regards his knowledge of the industry, we all know he worked for one of the major oil companies for twenty years. He therefore knows the oil industry from the inside and appreciates the kinds of problem which face an oil company.

In the academic field, anyone acquainted with Professor Garner's work at Birmingham University and the inspiration which he gives to his students is aware of the value of what he has achieved.

On the public-relations side in membership of Government Committees and the like, Professor Garner is to be found whenever help and guidance is required.

I suppose the Institute of Petroleum owes more to Professor Garner than to almost anyone at the present time.

I do not think I can do more than just end on a simple note by saying that there cannot be a more patient, persistent, and persuasive seeker after truth than Professor Garner, and we all owe a great deal to him.

I now present on behalf of the Institute of Petroleum, the Redwood Medal.

PROFESSOR GARNER expressed his great appreciation of being the recipient of the Redwood Medal, particularly bearing in mind the many distinguished people on whom it has been conferred.

This concluded the proceedings.

PERFORMANCE AND ACCURACY OF AMERADA BOTTOM HOLE PRESSURE RECORDER WITH SPECIAL REFERENCE TO USE IN DRILL STEM FORMATION TESTS AND REPEATABILITY OF RESERVOIR PRESSURES OBTAINED THEREIN

By A. Laird * and J. Birks *

Summary

A technique for the calibration and use of the Amerada Type RPG-3 gauge has been developed by which pressures can be determined with an accuracy better than ±0·05 per cent of the full-scale value of any individual pressure element. This improvement over the maker's quoted figure of ±0·25 per cent has been obtained primarily by using a diamond-pointed stylus which describes lines 0·0005 inches wide on black charts and scanning equipment giving a reading accuracy of ±0·0005 inches.

Before putting a pressure element into use, a detailed laboratory investigation is necessary to determine the variation of the temperature coefficient with pressure and the hysteresis curve for the element. The pressure-deflection characteristics of a gauge change with use, and it is necessary to bracket the unknown with standard pressures using a dead-weight tester. The pressure is computed from the deflections, using the method of proportionation, and corrected for temperature and hysteresis.

The techniques described were applied to measurements made during duplicate Packer Tests, and gave reservoir pressures in agreement within the limits quoted, *i.e.*, ±2 p.s.i. over the range of the 4000-p.s.i. element.

Introduction

The Amerada Bottom Hole Pressure Recorder has been employed very successfully by the D'Arcy Exploration Company on its U.K. fields since 1939 for general routine work and also for obtaining complete pressure records in packer tests. The comparatively simple calibration procedure adopted, which involved describing lines at suitable intervals on the charts using a dead-weight tester directly connected to the instrument, was perfectly satisfactory for the work in this area where small pressure differences are not, in general, of great importance.

The use of precision instruments such as the Amerada in formation testing was a new and important development. The work in the U.K. had shown them to be sufficiently robust for this exacting duty, but in view of the extension of the technique to operations on the major oilfields of the Middle East, where pressure decline is very small indeed at the high production rates, considerable improvement in accuracy was clearly desirable. A thorough investigation of the performance of the Amerada was, therefore, undertaken, the major objectives being to produce more clearly defined charts and improved scanning apparatus, to develop a suitable calibration technique following a study of the effect of different variables on the pressure-deflection characteristics of the pressure elements and to determine the accuracy and repeatability obtainable in the field.

* Anglo-Iranian Oil Company.

Review of Investigations Carried Out in the United States of America

Brownscombe and Coulon [1] reported the use of a hard metal stylus and black-coated charts to improve the accuracy of measurement to within 0·0002 inches and the development of a technique for applying calibration pressures at reservoir temperature within 50 p.s.i. of the pressure to be measured before and after a run. A standardized procedure was adopted for describing the zero pressure line, the position of which depends on temperature and usage of the element. They noted that the characteristics of pressure elements might change during the course of a run. In later work Brownscombe [2] observed that 1 hour should be allowed for the gauge to reach thermal equilibrium and that pressure equilibrium was obtained almost immediately on application of pressure. Hysteresis effects were also observed, and it was shown that errors of 25 p.s.i. in 2000 p.s.i. could be introduced by computing a decreasing pressure from calibration data obtained with rising pressures.

Perkins and Chaney [3] developed the use of linear equations to relate pressures to deflections rather than the use of curves. Smith and Dewees [4] used the method of least squares to fit the best straight-line relationship to the pressure-deflection results. This enabled them to isolate the following sources of errors :—

1. Inherent errors due to—
   (*a*) reproducibility of the gauge;
   (*b*) change in characteristics with usage.
2. Avoidable errors due to—
   (*a*) use of poor charts and stylus points;
   (*b*) pressure shocks during calibration;
   (*c*) failure to reach thermal or mechanical equilibrium;
   (*d*) neglect of the effect of barometric pressure inside the pressure-element housing;
   (*e*) change of zero pressure correction with temperature.

Basing their calibration on the development of an equation of the type

$$P = m\Delta + a$$

where P is the pressure in p.s.i.g., m is the gauge modulus, Δ the deflection, and a the zero pressure correction, measurement of $\left(\frac{dm}{dT}\right)$ and $\left(\frac{da}{dT}\right)$ over the temperature range required must be made. From the results quoted for a 1200-p.s.i.-range element they showed that these two factors were constant throughout the temperature range 60° to 120° F.

The disadvantage of the method is that the zero pressure correction has to be determined every time the instrument is used in the field, and there always remains uncertainty concerning the rest position of the element at zero pressure: furthermore, any slight error in the modulus value is magnified at the higher pressures.

The performance of a 1200-p.s.i. element was observed in the field over a period of seven months, and no significant change in characteristics was

noted. In general, the authors quote a standard deviation of ±0·05 per cent of the full-scale value as the accuracy obtainable.

In all the previous work described the reference line used was a zero pressure line either corrected for temperature or applied under standard conditions. This required measurement of distances up to 2 inches with an accuracy of 0·0005 inches. All field measurements had been made with the Amerada run on a wire line.

Investigation—Experimental Work and Discussion of Variables

Preliminary

(a) *Recording*

A comparison of the traces obtained using gold, steel, and diamond-pointed stylii indicated that the latter gave the best performance when used on black-coated charts. A diamond point, ground to an included angle of 90° and rounded off to a radius of 0·0005 inches, was mounted on the stylus spring, and the tension of the spring adjusted so that lines less than 0·0005 inches wide were described.

(b) *Scanning*

A relatively cheap and accurate scanner, sufficiently robust for use in the field and allowing quick reading of distances up to 0·25 inches with an accuracy of 0·0005 inches or up to 0·5 inches with an accuracy of 0·001 inches, was successfully developed in co-operation with R. & J. Beck Ltd., London.

For tracing "build-up" and "decline" curves, a Cambridge Universal measuring instrument is preferable, but the Beck instrument may be used if a time scale is marked on the chart by hand.

(c) *Chart Reproduction*

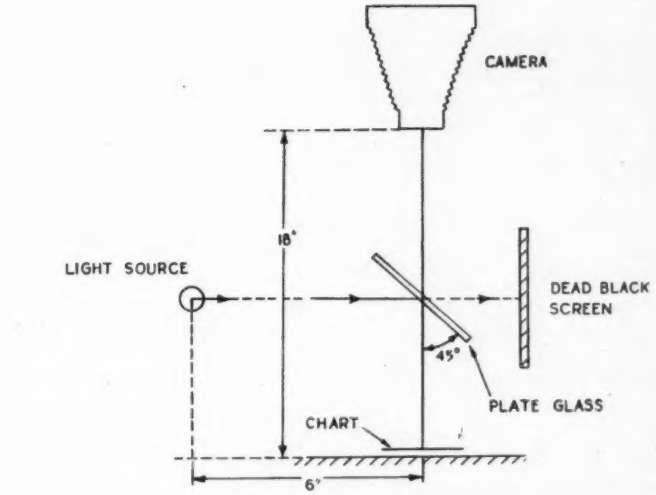
Clearly defined and reasonably accurate reproductions of original charts are invariably required for record purposes. A method for photographing black Amerada charts, which is illustrated in Fig. 1, was therefore developed.

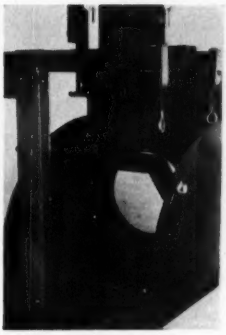
The light source illuminating the chart should be of even intensity, otherwise the lines towards the ends of the chart will fade out in the photograph. A Point-o-light lamp is used with a large condensing lens adjusted to give an even patch of light approximately 7 inches in diameter. The glass plate A is set at approximately 45° and so adjusted that the pressure lines on the chart are evenly illuminated when viewed along the axis of the camera.

Typical examples are given in the text.

Pressure-deflection Characteristics

Preliminary studies on the pressure-deflection characteristics of six Amerada pressure elements (Type RPG-3 ranges 1200, 2000, 4000, and





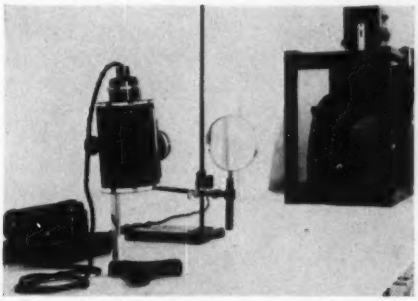


FIG. 1

ARRANGEMENT FOR PHOTOGRAPHING BLACK AMERADA CHARTS

[*To face p.* 680.

7400 p.s.i.) indicated that the errors involved in pressure determinations were less than $\pm 0{\cdot}05$ per cent of the full-scale value of any individual pressure element (*i.e.*, ± 2 p.s.i. for a 4000-p.s.i. element).

(a) *Non-Effective Variables*

The pressure-deflection characteristics were shown to be independent of the following variables, within the accuracy of measurement $\pm 0{\cdot}0005$ inches—

1. Direction of Movement of the Chart with Respect to the Stylus, *i.e.*, whether travelling up or down the time axis at a given applied pressure.
2. The Relaxation Time of the Pressure Element at Zero Pressure.
3. The Time of Application of Pressure.

In a series of experiments with a 2000-p.s.i. element, pressure lines were described at 1407 p.s.i. at intervals of time 0, 10, 20, and 30 minutes during continuous application of pressure and the deflections from a 1427-p.s.i. calibration line compared. No change in deflection was observed, indicating that pressure equilibrium is attained within a few seconds of application of pressure.

4. The Rate of Build-Up of Pressure.

The deflections obtained with immediate build-up of pressure (by hand-pump over, say, 20 seconds) and with slow uniform build-up to simulate running the gauge into a well (30 minutes allowed) were compared in the laboratory at 804, 904, and 1005 p.s.i. on a 2000-p.s.i. element. No differences exceeding 0·0005 inches could, however, be distinguished between the two sets of lines described.

A field test was carried out, using the same 2000-p.s.i. element to compare the pressures obtained when running the gauge to 2500 ft in 4 minutes and 30 minutes respectively. The gauge was left at 2500 ft for 1 hour after each run to allow thermal equilibrium to be attained. The pressures recorded, 1084 ± 2 p.s.i., indicated no significant effect on deflection of rate of build-up of pressure.

(b) *Effective Variables*

The following variables affect the deflection at any applied pressure :—

1. Temperature of the gauge.
2. Hysteresis—direction of approach to the pressure, *i.e.*, whether a falling or rising pressure.
3. The increase in air pressure due to temperature increases in the Amerada case.
4. The point of application of the pressure, *i.e.*, whether around the pressure bellows, or around the pressure element, or around the whole gauge.
5. Change in gauge characteristics with usage.

These variables are discussed below in detail, since their relative importance decides the method of calibration and use of the gauge.

(1) *Temperature.* The effect of temperature on a deflection Δ obtained

at an applied pressure P is characterized by the temperature coefficient C, which is defined as the change in deflection per degree Fahrenheit. *e.g.*,

$$C = \frac{\Delta_2 - \Delta_1}{T_2 - T_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where Δ_1 = the deflection from the zero gauge pressure line at pressure P and temperature T_1; and

Δ_2 = the deflection from the aero gauge pressure line at pressure P and temperature T_2

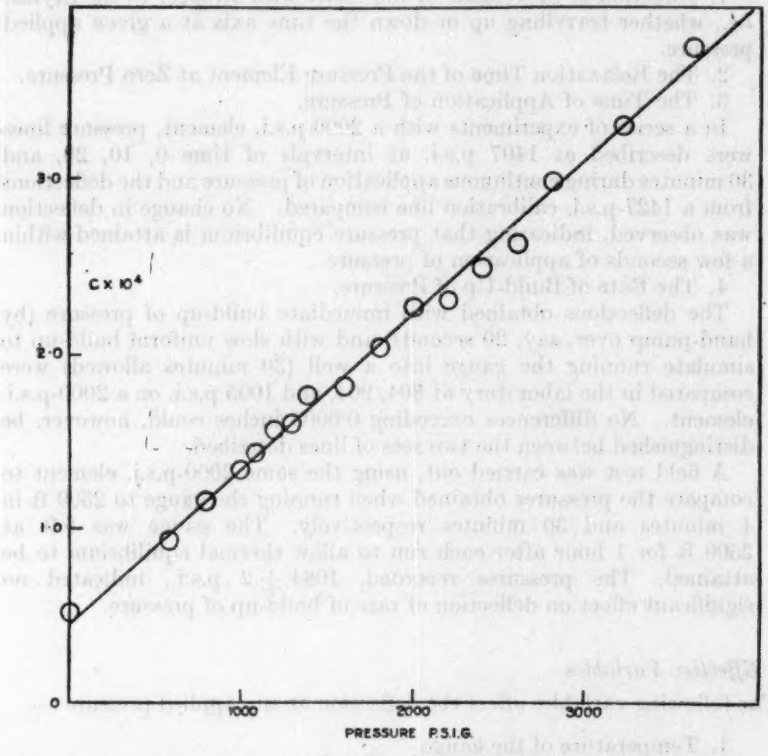


FIG. 2

TEMPERATURE COEFFICIENT PRESSURE CURVE, AMERADA RPG-3, ELEMENT 5703-B

The results obtained over the temperature range 45° to 150° F on six pressure elements, of ranges 1200, 2000, 4000, and 7400 p.s.i., indicated that C is a linear function of pressure and is independent of temperature.

This conclusion is supported by the work of Smith and Dewees [4] on a 1200-p.s.i. element which showed that the change in modulus and zero correction factor with temperature were constant throughout the temperature range 60° to 120° F.

A typical graph of temperature coefficient plotted against pressure is given in Fig. 2.

The relationship may be expressed as

$$C = PS + K. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where S = slope of the C–P curve;
P = pressure in p.s.i.g.;
K = zero gauge pressure temperature coefficient.

The constants of equation (2) for a particular element are independent of the method of application of pressure and change little with usage of the element (see Table I).

In the case of element 5703-B, an error of 6 p.s.i. in 2400 p.s.i. could be introduced by using a mean temperature coefficient or a figure derived from the makers' calibration chart, for a temperature correction of 70° F.

(2) *Hysteresis.* The deflection obtained at a pressure P when this is reached from a lower value is less than that obtained when P is approached from a higher value. This difference between the deflection observed is the hysteresis effect and its magnitude is a function of P and the pressure

TABLE I

Pressure Element : 5703-B
Range : 0 to 4000 p.s.i.g.

Operator	$S \times 10^7$ (inches per p.s.i/° F)	$K \times 10^4$ (inches/° F)
Makers (June 1946) . .	1·05	0·53
A.I.O.C. (July 1948) . .	0·85	0·43
A.I.O.C. (Dec. 1948) . .	0·90	0·45

drop involved. As a standard of reference all hysteresis effects are considered to be due to falling pressure.

Typical hysteresis curves for a 4000-p.s.i. element, shown in Fig. 3, exhibit a maximum hysteresis at the midpoint of the pressure interval, *e.g.*, the hysteresis at 2000 p.s.i. when pressure is reduced from 4000 to 2000 p.s.i. is 32 p.s.i., whereas the hysteresis at 3000 or 1000 p.s.i. when pressure is reduced from 4000 p.s.i. to these values is 22 p.s.i. Similar curves are obtained for a 2000-p.s.i. element; the magnitude of the hysteresis is, however, approximately only one-half of the values obtained for the 4000-p.s.i. element.

Studies made over a wide range of pressures, both under laboratory and well conditions, indicated that the effect of temperature (50° to 150° F) on the nature of the hysteresis curves is negligible, and that the hysteresis does not change with the time of application of pressure. In one well experiment, where pressures were compared at a series of depths when running in and pulling out, no change in the magnitude of the hysteresis could be observed after 1 hour.

In formation test operations, on setting the packer, a pressure surge of up to 1000 p.s.i. greater than the reservoir pressure may occur in the sump. If the pressure in the sump is allowed to come to equilibrium at reservoir pressure, the Amerada will record a "falling pressure." If, for example, the reservoir pressure were 2000 p.s.i. the hysteresis effect would be of the

order of +15 p.s.i. on a 4000-p.s.i. element. The 15 p.s.i. should, of course, be deducted from the falling pressure calculated from the deflection to give the correct value.

(3) *The Increase in Air Pressure inside the Amerada Case Due to Temperature Increase.* The Amerada gauge is normally assembled at room temperature and atmospheric pressure before use. Under well conditions the temperature of the instrument usually rises, thus causing a corresponding increase in air pressure inside the case which acts on the outside of the pressure spiral.

This effect was observed by Smith and Dewees,[4] who reported that an increase in internal air pressure of 1 p.s.i. reduced the deflection at any pressure between 0 and 1200 p.s.i.g. by an amount equivalent to 1 p.s.i. This work was extended to cover the range up to 3 p.s.i., whilst operating the pressure gauge over its full range at room temperature, 60° F, and at an

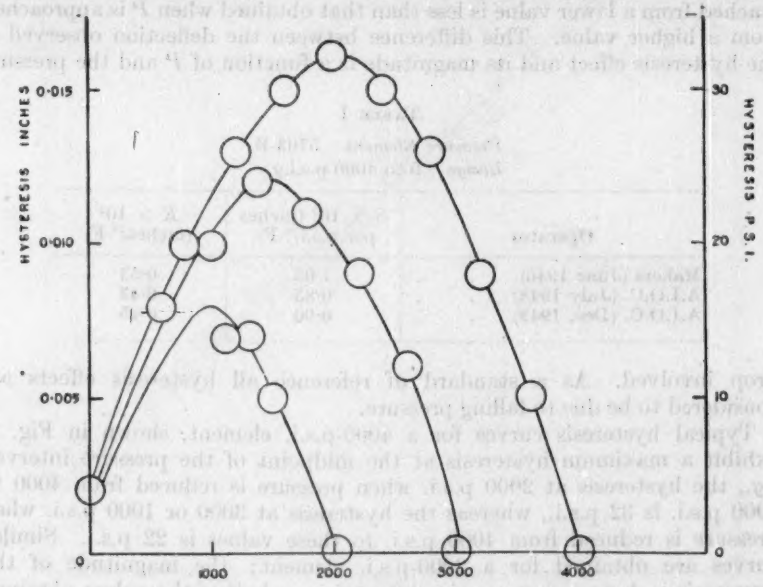


FIG. 3

HYSTERESIS CURVE, ELEMENT 5703-B

elevated temperature of 128° F. In the case of the 1200- and 2000-p.s.i. elements studied, the reduction in deflection was found to correspond exactly to the increase in air pressure. The instrument thus behaved like a differential manometer and was not affected by the method of application of the oil pressure, the magnitude of the oil pressure, or the temperature of the experiment.

The pressure correction for a temperature increase $\Delta T°$ F is readily calculated from the following equation :—

$$\Delta P = P \cdot \frac{\Delta T}{(T + 460)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where ΔP = pressure correction in p.s.i. to be added to the value determined from the chart deflection;
P = atmospheric pressure in p.s.i.a. at the time of assembly of the gauge;
T = temperature in ° F of assembly;
ΔT = temperature increase on T.

For a 100° F difference in temperature between the well and room temperature, the value of ΔP is 2·8 p.s.i.

Table II shows the results obtained at 64° and 128° F for a 1200-p.s.i. element.

TABLE II

Effect of Increase in Air Pressure Inside the Amerada Case on a 1200-p.s.i.g. Element.

Oil pressure (p.s.i.g.)	Decrease in deflection (inches) due to increases in air pressure of—					
	1·0 ± 0·1 p.s.i.		2·0 ± 0·2 p.s.i.		3·0 ± 0·2 p.s.i.	
	At 64° F	At 128° F	At 64° F	At 128° F	At 64° F	At 128° F
0	0·0022	0·0020	0·0030	0·0031	0·0041	0·0047
201	0·0022	0·0016	0·0033	0·0031	0·0049	0·0045
603	0·0020	0·0018	0·0033	0·0035	0·0043	0·0045
804	0·0018	0·0018	0·0037	0·0033	0·0047	0·0040
1005	0·0020	0·0022	0·0039	0·0028	0·0045	0·0040
Mean decrease in deflection . .	0·0020	0·0019	0·0034	0·0032	0·0045	0·0043
Equivalent mean pressure decrease	1·2 p.s.i.	1·1 p.s.i.	2·0 p.s.i.	1·9 p.s.i.	2·7 p.s.i.	2·6 p.s.i.

(4) *The Point of Application of Pressure.* Studies on three pressure elements, ranges 2000, 4000, and 7400 p.s.i., indicated that when oil pressures were applied directly to the pressure bellows (by means of an adaptor screwed on in place of the oil trap Y-3109) rather than around the entire instrument as in a well, the deflections obtained were slightly greater. The error involved is of the order of 0·1 per cent of the full-scale value of a pressure element, *i.e.*, 2 p.s.i. for a 2000-p.s.i. element.

Table III shows the mean of two series of runs at 60° F on a 2000-p.s.i. element. The pressures were applied as detailed below and recorded on one chart. The whole series was repeated on a second chart.

(*a*) Pressures applied direct to the pressure element by means of the base adaptor.
(*b*) Pressures applied around the instrument up to the level of the top of the pressure element.
(*c*) Pressures applied around the complete assembly.

There appears to be no obvious mechanical reason for these differences, but since they were observed in the three elements tested, it was considered undesirable to apply calibration pressures by means of a screwed-on adaptor.

Since also it appears immaterial whether pressures are applied around the pressure element or the whole instrument, the design of the calibration pressure vessel (see Fig. 5) follows the former practice.

(5) *Change in Gauge Characteristics with Usage.* One of the principal characteristics of the Amerada pressure spiral is that the pressure-deflection

TABLE III

Applied pressure (p.s.i.g.)	Difference in deflections (inches)	
	(*a*–*b*)	(*b*–*c*)
0	−0·001	−0·0001
201	0	0
402	0	0
603	0·0005	0
804	0·0005	0
1005	0·001	0
1206	0·0015	0
1407	0·002	0
1608	0·002	0
1809	0·002	0

curves at any particular temperature are remarkably linear over the greater part of the pressure range, and the makers have, therefore, prepared calibration curves to enable pressures to be determined graphically from the deflections obtained. They also determine a mean temperature co-efficient to allow temperature corrections to be applied.

Unfortunately, apart from the errors introduced by using a mean

TABLE IV

Applied pressure (p.s.i.g.)	Deflection in inches from zero line at 46·5° F			
	T = 46·5° F		T = 146·5° F	
	1946 Makers	1948 A.I.O.C.	1946 Makers	1948 A.I.O.C.
0	0	0	0·005	0·005
800	0·292	1·393	0·406	0·404
1600	0·784	1·791	0·807	0·809
2400	1·178	1·188	1·208	1·212
3200	1·574	1·585	1·609	1·618
3800	1·871	1·883	1·912	1·921

temperature coefficient, two other errors are introduced. First, deflections are necessarily measured from a zero gauge pressure line which itself is subject to hysteresis. Secondly the pressure-deflection characteristics change with use. The effect is equivalent to a weakening of the spiral, since the deflection at a particular temperature and pressure increases.

Table IV shows the effect of use on the characteristics of a 4000-p.s.i. element.

It is clear that no reliance can be placed on the accuracy of a pressure-deflection calibration curve over a period of time and that it is essential,

when calculating an unknown pressure from its deflection, to bracket the line with pressures from a dead-weight tester, *i.e.*, in effect repeating the calibration over the particular range required. By proportionation and application of a temperature correction, the unknown pressure may be readily calculated without reference to a zero gauge pressure line or a calibration curve. The method is described in the following section.

Determination of an Unknown Pressure from the Chart Deflection by the Bracketting Procedure

Referring to Fig. 4, the difference between the calibration lines bracketting the unknown pressure line is recorded (Δ''), and also the difference (δ'') between the lower calibration line and the unknown.

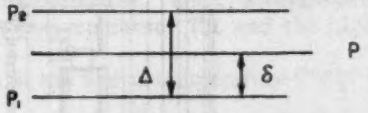


FIG. 4

If T_1 = calibration temperature ° F;
T_2 = well temperature ° F;
P_1P_2 = bracketting calibration pressures in p.s.i.g. described at T_1;
P = unknown pressure p.s.i.g.;
C_1 = temperature coefficient at P_1 in inches per ° F; and
C_2 = temperature coefficient at P_2 in inches per ° F.

Then,

$$P = P_1 + (P_2 - P_1) \cdot \left[\frac{\delta - C_1(T_2 - T_1)}{\Delta + (C_2 - C_1)(T_2 - T_1)} \right] \quad . \quad . \quad (4)$$

If the pressure P is a " rising pressure " there is no hysteresis correction to apply.

If the correction for the increase in air pressure inside the Amerada case has not been included in the temperature coefficient, this will have to be added to the value of P determined above (see equation (3)).

THE CALIBRATION OF THE PRESSURE ELEMENT

The apparatus required, illustrated in Fig. 5, comprises a pressure vessel with the necessary valves and pressure connexions, a thermostat regulated to $\pm 1°$ F, and a dead-weight tester accurate to $\pm 0{\cdot}1$ p.s.i.

1. *Amerada Assembly*

The instrument and apparatus are prepared for calibration as follows. Remove the clock outer housing cover, and thermometer well. Assemble the pressure element selected. Fit a diamond stylus to the stylus arm and insert the black-coated chart into the chart-holder. Fit the chart-holder on to the push-rods and ensure free travel of the chart-holder along the guides of the inner housing. Wind up the chart-holder to the top of its

travel by the hand-drive key and put the stylus on the chart. Plug the key to prevent the chart-holder running down when the gauge is placed vertically. Replace the outer housing by a steel tube of the same diameter. The top of the adaptor is normally open to atmosphere, so that the hand-drive key may be readily operated. (If the effects of air pressure increase

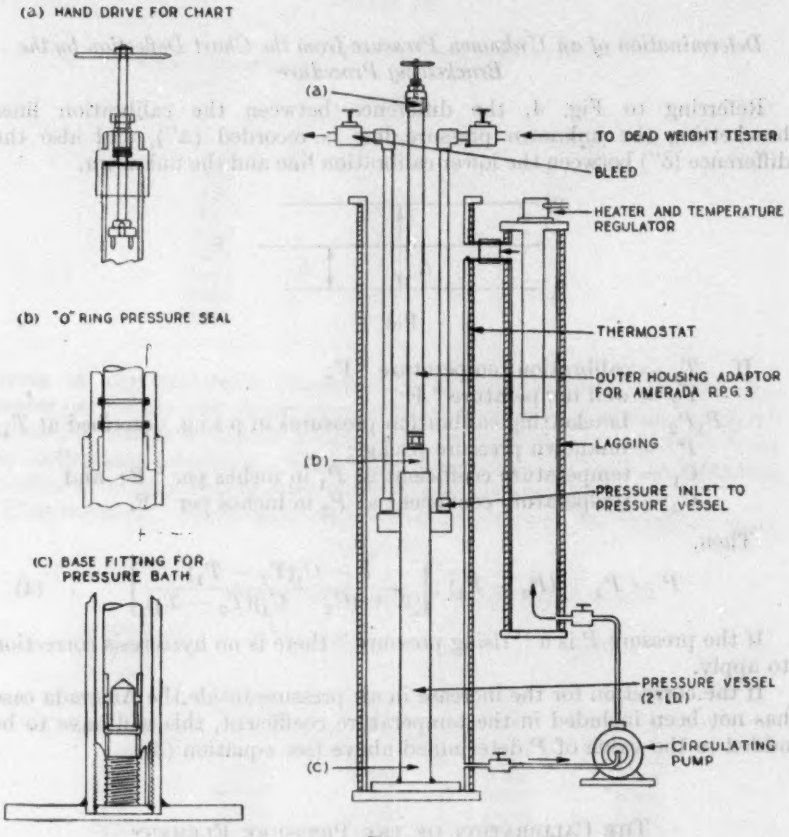


FIG. 5

APPARATUS FOR CALIBRATION OF AMERADA RPG-3.

inside the Amerada case due to temperature increase are to be included in the temperature coefficient, a pressure gland may be screwed on top of the adaptor, see Fig. 5 (*a*). This is not normally done, since such effects are small and are readily calculable.) A base plug is screwed on in place of the thermometer well, this plug threading into the base fitting of the pressure bath.

The Amerada assembly is slipped through the "O" ring seal of the pressure bath and the base fitting engaged. The side-arm connexions of the pressure bath are screwed up against Dowty ring seals. The whole

assembly is lowered into the thermostat and connected up to a dead-weight tester. A second valve is provided for bleeding off air during the initial stages of pressure build-up by hand-pump or for pressure reduction.

2. *Calibration Procedure*

The limit of travel of the chart-holder along the time axis is equivalent to fourteen turns of the hand-drive key, when using the normal single-pitch lead-screw assembly.

The arrangement of the chart is designed to give the following information :—

(*a*) hysteresis at the lower temperature $T.1$ (0 to $3\frac{1}{2}$ turns of the hand-drive key);

(*b*) temperature-coefficient and pressure-deflection calibration between the lower temperature $T.1$ and the higher temperature $T.2$ (4 to 6 turns);

(*c*) hysteresis at the higher temperature $T.2$ (7 to 11 turns).

The method is illustrated by the photograph of the calibration chart of a 4000-p.s.i. element, Fig. 6 (*a*), and a sketch showing the arrangement of the pressure lines, Fig. 6 (*b*). The chart was wound back to the top of its travel at approximately 400 p.s.i. to allow the change in the position of the zero pressure lines to be distinguished.

At both temperatures $T.1$ and $T.2$, hysteresis measurements were made from 4000, 3000, and 2000 p.s.i. down to the pressure being measured. The differences in deflections between rising and falling pressures were measured directly.

A temperature coefficient at pressure P was measured from the difference in deflection between pairs of lines drawn at temperatures $T.1$ and $T.2$ and pressure P.

The lines marked zero 1 and zero 2 on Fig. 6 (*b*), refer to the zero gauge pressure lines described before and after the calibration operations at temperature $T.1$. Similarly, zero 2 and 4 refer to temperature $T.2$.

Pressure-deflection measurements were referred to zero 2 (Fig. 6(*a*) and (*b*)).

3. *Calibration Results*

A summary of the results obtained for the 4000-p.s.i. element 5703-B are given in Table V, VI, and VII.

The results of Table V indicate the effect of hysteresis on the position of the zero gauge pressure line and show that errors of up to 4 p.s.i. may be

TABLE V

The Difference in Deflection between Lines Measured from Zero 1

Zero gauge pressure lines	Deflection in inches
Zero 1	0
Zero 2	0·0016
Zero 3	0·0047
Zero 4	0·0067

introduced using a 4000-p.s.i. element if measurements are made from a non-standardized zero line when computing pressure from deflection.

The application of the method of least squares to fit pressure-deflection data to a straight-line relationship has been used by several authors.[4,5] To illustrate the linearity of the relationship the method has been applied to

TABLE VI

Pressure-Deflection Results and Temperature Coefficients (Fig. 2)

Applied pressure (p.s.i.g.)	Δ deflections in inches from Zero 2		$\Delta_2-\Delta_1$	Temperature coefficient ($C \times 10^4$)
	Δ_1 at 46·5° F	Δ_2 at 146·5° F		
0	0	0·0051	0·0051	0·51
603·0	0·2961	0·3055	0·0094	0·94
804·0	0·3953	0·4070	0·0117	1·17
1005·05	0·4945	0·5079	0·0134	1·34
1105·56	0·5449	0·5594	0·0145	1·45
1206·1	0·5941	0·6098	0·0157	1·57
1306·6	0·6441	0·6602	0·0161	1·61
1407·1	0·6937	0·7114	0·0177	1·77
1507·6	0·7457	0·7616	0·0159	1·59
1608·2	0·7949	0·8132	0·0183	1·83
1809·2	0·8939	0·9144	0·0205	2·05
2010·25	0·9929	1·0157	0·0228	2·28
2211·3	1·0941	1·1173	0·0232	2·32
2412·3	1·1937	1·2188	0·0251	2·51
2605·3	1·2898	1·3163	0·0265	2·65
2806·7	1·3889	1·4189	0·0300	3·00
3200·4	1·5850	1·6183	0·0333	3·33
3595·1	1·7809	1·8187	0·0378	3·78

TABLE VII

Hysteresis Results

Applied pressure p (p.s.i.g.)	Pressure dropped from $P.1$ (p.s.i.g.)	Hysteresis (inches)	
		At $t_1 = 46·5°$ F	At $t_2 = 146·5°$ F
3595	4000	0·005	0·004
3200	4000	0·010	0·009
2807	4000	0·014	0·013
2412	4000	0·015	0·015
2010	4000	0·018	0·016
1608	4000	0·015	0·015
1206	4000	0·014	0·013
804	4000	0·011	0·009
2605	3000	0·007	0·006
2211	3000	0·008	0·009
1809	3000	0·011	0·011
1407	3000	0·014	0·011
1005	3000	0·012	0·010
603	3000	0·007	0·007
1508	2000	0·005	0·006
1307	2000	0·009	0·007
1106	2000	0·008	0·006

selected results from Table VI at 146·5° F. The important point to bear in mind, however, is that although an accurate linear relationship may be found, this relationship may alter with usage of the gauge and such results hold only at the time of calibration. Furthermore, the linearity of the relationship justifies the method of proportionation adopted when calculating a pressure from its deflection relative to the position of bracketting calibration pressures.

The linear relationship between pressure and deflection may be represented as :—

$$P = m\Delta + a \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Where P = pressure in p.s.i.g.;
Δ = deflection (from zero 2) in inches;
m = gauge modulus in p.s.i.g. per inch deflection;
a = zero pressure correction in p.s.i.

By the method of least squares

$$m = \frac{\Sigma(P)\Sigma(\Delta) - n\Sigma(P\Delta)}{(\Sigma\Delta)^2 - n\Sigma(\Delta^2)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and

$$a = \frac{\Sigma(\Delta)\Sigma(P\Delta) - \Sigma(\Delta^2)\Sigma(P)}{(\Sigma\Delta)^2 - n\Sigma(\Delta^2)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and results are shown in Table VIII, the empirical relationship being :—

$$P = 1977{\cdot}43\Delta + 0{\cdot}45 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The pressure-deflection relationship is linear except at the ends of the range, and the determination of pressures from this relationship may lead to errors of up to 2 p.s.i.

TABLE VIII

Example of the Method of Least Squares for Fitting Deflections and Pressures to a Linear Equation (the Deflections are Referred to a Zero Pressure Line Placed on the Chart at 46·5° F)

Temp. (° F)	P.S.I. applied	Δ (inches)	$P \times \Delta$	Δ_2	Pc computed	$P-Pc$ (p.s.i.)
146·5	804·0	0·4070	327·22800	0·16564900	805·26	−1·3
	1206·1	0·6098	735·47978	0·37185604	1206·29	−0·2
	1608·2	0·8132	1307·78824	0·66129424	1608·5	−0·3
	2010·3	1·0157	2041·86171	1·03164649	2008·93	+1·4
	2412·3	1·2188	2940·11124	1·48547344	2416·54	+1·8
	2806·7	1·4189	3982·42663	2·01327721	2806·23	+0·5
	3200·4	1·6183	5179·20732	2·61889489	3200·52	−0·1
	3595·1	1·8187	6538·40837	3·30766969	3596·8	−1·7
Sum :	17643·1	8·9204	23052·51129	11·65576100	Σ Deviations	7·3

Mean deviation = 0·9 p.s.i.

Standard deviation = 1·0 p.s.i.

The temperature-coefficient pressure results are plotted in Fig. 2, the equation of the straight line being

$$C = (0{\cdot}90 \times 10^{-3}\, P + 0{\cdot}45)\, 10^{-4} \text{ inches per } ^\circ \text{F} \quad . \quad . \quad (9)$$

Where P = pressure in p.s.i.g.

The error in the value of C is of the order of $0{\cdot}05 \times 10^{-4}$, which would introduce an error of ± 1 p.s.i. in a reservoir pressure determination for a difference between calibration and reservoir temperatures of 100° F. The obvious procedure is to apply the calibration lines at a temperature as near that of the reservoir as practicable.

The hysteresis results of Table VII have been smoothed and plotted in Fig. 3. The form of the hysteresis curves is substantially independent of the temperature; maximum hysteresis is exhibited at mid-point of the pressure interval.

Performance in the Field

The D'Arcy Exploration Company records of packer tests carried out over the past four or five years show that the Amerada instrument is sufficiently robust for this duty. One particular 2000-p.s.i. element has been used on 164 occasions over this period, in addition to the usual routine static bottom-hole measurement, and is still in commission.

Duplicate packer tests were carried out on Mansfield Well No. 1, on the carboniferous limestone, with a view to demonstrating that the degree of accuracy indicated in the laboratory is attainable under such exacting field conditions. Amerada pressure element No. 5703-B, range 0 to 4000 p.s.i., was used, and the procedure in both tests was identical.

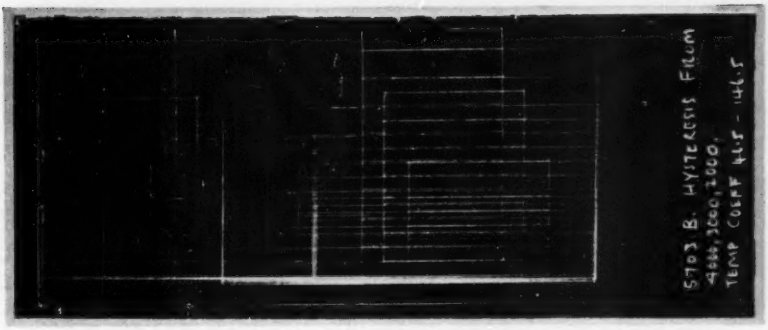
Calibration lines were described on the chart at a temperature of 59° F at dead-weight pressures of 0, 201, 402 p.s.i. and thereafter at 401-p.s.i. intervals up to 2412 p.s.i.g. The Amerada was assembled in the laboratory with a 12-hour clock and transported in shock absorbers to the well where the outer housing cover was removed. The gauge was placed in a horizontal position, the clock disengaged from the chart movement (which was at the top of its travel), wound up, started, and re-engaged with the chart movement–zero time. The outer housing was replaced and made pressure-tight.

The gauge was suspended from the top inside a 6-ft length of $1\frac{1}{2}$-inch pipe, open at both ends and fitted with shock absorbers. This assembly was then mounted in the bottom " pony " joint of the packer string. The " pony " is a 9-ft length of $3\frac{1}{2}$-inch drill pipe, isolated from the remainder of the anchor string by means of a $\frac{1}{4}$-inch-thick plate welded inside immediately below the tool joint; two $\frac{1}{2}$-inch holes drilled opposite each other near the top allow pressure connexions between the sump and the gauge. Before running in, the " pony " was filled with water to prevent mud clogging of the Amerada oil seals and bellows; one of the $\frac{1}{2}$-inch holes was then plugged.

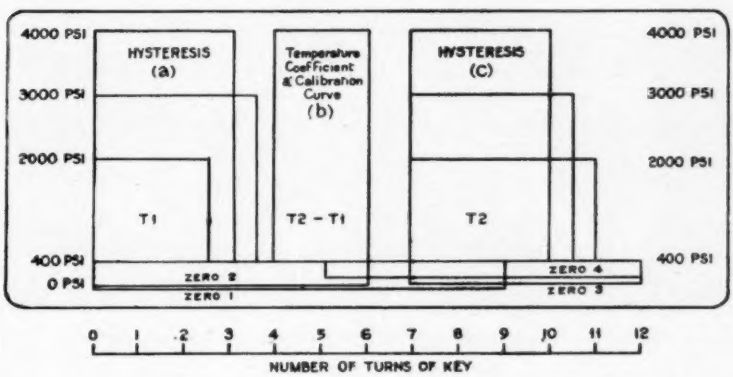
The drilling fluid used in the well was crude oil; a water show was encountered in the limestone.

The stages of the formation tests may be followed on photographic copies of the two pressure records obtained Fig. 7.

1. Clock started, Amerada and packer string assembled.
2. 2 hours' running-in.
3. Set 2 ft from bottom of $5\frac{3}{8}$-inch hole for 20 minutes for a drilling-fluid pressure.

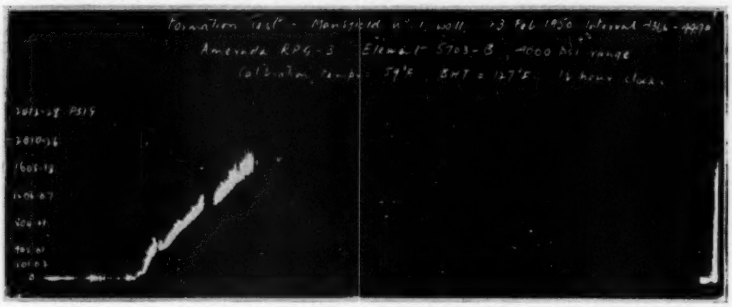


(*a*) PHOTOGRAPH OF CALIBRATION CHART OF 4000 P.S.I. ELEMENT 5703-B

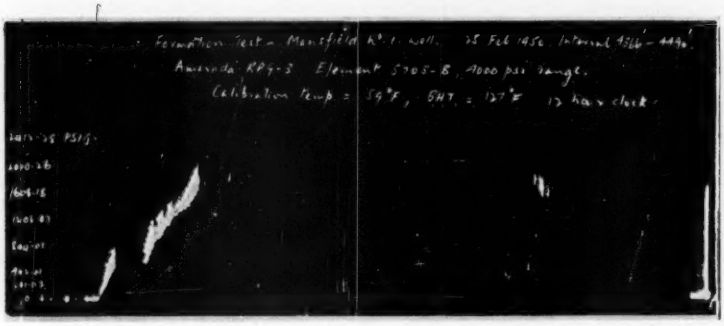


(*b*) SKETCH OF THE ARRANGEMENT OF THE CALIBRATION CHART

FIG. 6



FORMATION TEST 1, FEBRUARY 23, 1950, MANSFIELD WELL NO. 1
CHART 1



FORMATION TEST 2, FEBRUARY 25, 1950, MANSFIELD WELL NO. 1
CHART 2

FIG. 7

[*To face p.* 693.

4. Set 3½-inch J slot Halliburton packer rubber at 4366 ft. Allowed 2 hours for first reservoir pressure.

5. Opened and closed the tester valve. Allowed 3 hours for second reservoir pressure.

6. Opened tester valve and allowed production into the drill pipe for 12 hours.

7. Closed tester valve and pulled out.

8. Dismantled Amerada, read maximum indicated thermometer (127° F) and removed chart.

9. Read the chart with a travelling microscope, photographed chart.

In the second test, at the beginning of the second reservoir pressure determination, the effect of opening and closing the Tester valve twice can be seen as a surge of approximately 1000 p.s.i. The production test in the second test was abandoned after ½ hour, due to plugging of the perforations in the pipe below the rubber and leakage past the rubber. The pressure records, however, were not effected, since they were obtained before the production test.

The two drilling-fluid pressures were 1964 and 1718 p.s.i., corresponding to different quantities of water in the hole at the beginning of each test.

Examination of the pressure charts from both tests indicated that the first reservoir pressures had not reached equilibrium, although the second reservoir pressures appear to have done so.

The accurate analysis of the rate of pressure rise in such a system is extremely complicated, and may be represented by the sum of exponential terms. However, for practical purposes, the pressure–time relationship over the last 50 p.s.i. pressure build-up fit an exponential relationship of the type

$$P = P_\infty - (P_\infty - P_0)e^{\alpha t} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where P_∞ is reservoir pressure, P is the sump pressure recorded at time t and P_0 is the sump pressure at $t = 0$. Taking the last 50 p.s.i. as exponential $P_0 = P_\infty - 50$.

The semi-logarithmic method of extrapolation of the pressure-deflection curves to infinite time may therefore be used, following the procedure of Muskat,[5] or using the method of differences of Arps.[6] The former method is more suitable, the deflection being extrapolated to infinite time. The results are shown in Table IX, from which it will be observed that the second reservoir pressures had actually reached equilibrium.

The mean value for the reservoir pressure is 1995 ± 2 p.si., and the agreement between the four results is excellent.

The pressures were calculated by means of equation (4), values of the temperature coefficients at 2010·3 and 2412·3 p.s.i.g. being $2{\cdot}26 \times 10^{-4}$ and $2{\cdot}62 \times 10^{-4}$ inches/° F respectively.

The correction for increase in pressure due to the rise in temperature of the air inside the Amerada case from 59° to 127° F was 1·9 p.s.i. in each case. This was added to the value obtained from equation (4) to give the values recorded in Table IX.

TABLE IX

Pressure line	Deflections in inches measured from the 1608·2 p.s.i.g. line		Pressure p.s.i.g. from Chart 1	Pressure p.s.i.g. from Chart 2
Calibration lines:	Chart 1	Chart 2		
1608·2 p.s.i.g.	0	0	—	—
2010·25 ,,	0·2008	0·2004	—	—
2412·3 ,,	0·4016	0·4008	—	—
Final value of 1st R.P. on chart	0·2055	0·2055	1994·1	1994·1
Extrapolated value of 1st R.P.	0·2071	0·2067		
Final value of 2nd R.P. on chart	0·2079	0·2075	1995·7	1995·7
Extrapolated value	0·2079	0·2075		

CONCLUSION

The technique described for calibrating and running the Amerada RPG-3 gauge should give results accurate to within ±0·05 per cent of the full-scale value of any selected pressure elements if adopted by skilled operators. The absolute accuracy of the determinations is governed, of course, by the accuracy of the dead-weight tester used.

The characteristics of some pressure elements may actually change, however, during the course of a single run, giving rise to errors as high as 15 p.s.i. in 4000 p.s.i., and it is, therefore, essential to check the reproducibility of new elements thoroughly under both laboratory and field conditions before they can be used with confidence for precision work.

Tests have recently been carried out in the Persian oilfields to compare static bottom-hole pressures measured by the Amerada and the Laird Pressure Indicator, which has been used there for many years. The results reported, which support the claims made regarding reproducibility and limits of accuracy, are given below.

TABLE X

Pressure Measurements on Well A by Ameradas RPG-3

Runs	Elevation in feet above datum	Pressure (p.s.i.g.)	
		From calibration lines described before run	From calibration lines described after run
1	11,100	1082·7	1082·9
	9,735	1123·2	1122·9
	8,731	1163·4	1163·0
2	11,100	1083·0	1083·2
	9,735	1122·9	1124·0
	8,731	1163·3	1163·4

TABLE IX

Comparison of the Pressures Measured, Using Two Ameradas RPG-3 and Two Laird Pressure Indicators in Well B

Elevation in feet above datum in Well B	Instrument	Pressure (p.s.i.g.)
5710	Laird P.I. No. 1	2948·9
5710	Laird P.I. No. 2	2951·9
5710	Amerada No. 1 (RPG-3)	2950·3
5710	Amerada No. 2 (RPG-3)	2950·9
8269	Amerada No. 1 (RPG-3)	2716·8
8269	Amerada No. 2 (RPG-3)	2715·8

ACKNOWLEDGMENTS

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BRIEF HISTORY OF THE SEARCH FOR OIL IN THE AUSTRALIAN COMMONWEALTH*

By (the late) ARTHUR WADE (Fellow)

INTRODUCTION

FIFTY years have passed since petroliferous gas, found in a well drilled for water at Roma, Queensland, led to hope of oil being found in Australia. It was about ten years later that the finding of surface seepages near Aitapi, in what was then German New Guinea, led to the formation of German companies to search for oil in that Territory. About the same time, seepages of oil were found by prospectors in the Vailala River basin in Papua, and the search began in that area. The results have been disappointing. After the expenditure of much effort and millions of pounds, a small quantity of oil is being produced in Australia by a company operating at Lakes Entrance, Victoria, while no commercial oilfield has yet been found either in Papua or the Mandated Territory of New Guinea.

In a general way the history of the search for oil in this region has followed the same stages as in other countries, although evolution of ideas and methods have been slower than in some other parts of the world. An early discovery of some importance would have quickened the pace, since it would have attracted or made available more capital and would have drawn speculative oil men, more efficient operators, and technicians to force development or conclusions in the region.

In earlier years, chance discoveries of gas in wells drilled for water, indications at the surface of what was thought to be oil, but which in most cases was not, allegations that a stretch of country "looked like Texas," hunches, and the arts of the diviner, were the foundations on which most drilling was done. In times of boom, prospectors turned from gold and other minerals about which they knew something to look for oil, concerning which they knew nothing. A syndicate or small company could always be formed on the basis of the discovery of something dark in colour or offensive in smell. Interest was always local and areas taken up small, often only a few acres. No wonder the search was unsuccessful. Applications to State Mines Departments during 1949 showed that this stage had not then entirely passed in Australia. Nevertheless, big changes have taken place during the past twenty years; not the least of these has been the change in the attitude of the public towards the search of oil. There is a demand for more information, including reports by geologists which were not considered necessary in the old days. Technical staffs and methods receive as much attention in prospectuses as lists of directors—a very great change indeed. The change in public opinion has been reflected in political opinion.

For a proper understanding of the history of oil search in the Australian region, some knowledge of the political side and changes in political machinery is necessary.

* Paper received June 1950.

Every state in the Australian Commonwealth has sovereign control of its mineral resources, although the Commonwealth Government controls the mineral resources of the Northern Territory, the Territory of Papua, and the Mandated Territory of New Guinea. The Mining Laws Regulations of each state differed from those of its neighbour : the ordinances regulating mining in the three Commonwealth Territories were all different. There was uniformity in one respect only—petroleum was treated as just another mineral on the same basis as coal or gold; only small areas could be taken up; small companies and individual prospectors were encouraged; regional prospecting was impracticable and large-scale operations impossible. Herein lies the explanation of the fact that it is only within the past few years that any of the major oil companies have interested themselves in the search for oil in Australia. All the early work was done by small local concerns.

Two facts brought about a change—Australia's great need of oil and the lack of success in finding any by local companies over a very long period. In 1936 the Commonwealth Government appointed an Oil Advisory Committee in order to stimulate the search by encouraging sounder and more up-to-date technique. A fund of £250,000 was set aside to finance the activities of the Committee and for the purpose of assisting Australian companies engaged in seeking for oil. In the same year the ordinances governing the search for oil in Papua and Australian New Guinea were liberalized so as to encourage investigations on a regional scale. The Papua Oil Development Co. Ltd., a subsidiary of the Shell Company, embarked on a programme of exploration in Western Papua, while Oil Search Ltd., of Sydney, commenced geological investigations in both Papua and the Mandated Territory of New Guinea. Further amendments were made in 1938, and these resulted in the Anglo-Iranian, Vacuum, and Oil Search Ltd. taking up extensive areas, joining forces, and forming the Australasian Petroleum Co. Pty. Ltd. in order to conduct an intensive investigation of areas considered to be the most promising in these Territories.

In Australia itself the Oil Advisory Committee drew the attention of the Commonwealth Government to the lack of uniformity in State legislation, the fact that it was completely out of touch with modern trends, and that, as it stood, large-scale investigations were impossible in Australia. The Committee prepared a Model Bill based on recent legislative developments in other parts of the Empire and recommended its submission to the various States. Most of the States accepted the suggestions made, and new Petroleum Acts based on the Model Act were passed within the next six months. The example of New Zealand stimulated quick action by the Australian States, for New Zealand had adopted a very similar Act in 1938.

This modernizing and broadening of legislation led to important results. Several of the larger old-established oil companies embarked on the search for oil in Australia for the first time. The Shell Company and the Superior Oil Company of California immediately took up large areas in Queensland. Caltex began operations in the Kimberley district of Western Australia. Later the Zinc Corporation joined forces with D'Arcy Exploration and the Vacuum Oil Company in taking up a large part of the Great Artesian Basin, comprising portions of South Australia, New South Wales, and the Northern

Territory. Other areas were also taken up in Western Australia and the Northern Territory. The study of regions rather than localities in the search for oil began for the first time in Australia. Other Australian and American companies have followed suit. Aerial surveys were made, geological and geophysical investigations commenced, high-powered rotary plant was brought from America, and deep tests were drilled for oil. The search for oil in the Australasian region has really commenced.

In 1940 the Oil Advisory Committee was disbanded, but in 1946 the Commonwealth Government set up a Bureau of Mineral Resources, one of the functions of which was to stimulate and assist in the search for oil in Australia and Australian Territories.

Victoria

The search for oil in the State of Victoria has been confined almost entirely to portions of two sedimentary basins which fringe the southern coasts of the state. Both areas consist of the continental portions of larger depressions in the basement rocks, the greater parts of which are now submerged in the Tasman Sea to the east and the Southern Ocean to the west.

The eastern basin which forms a crescent-shaped coastal area extends eastwards from Wilson's Promontory to the mouth of the Snowy River. Its land area constitutes most of the Gippsland district of Eastern Victoria.

Marine deposits consisting of soft calcareous sands, marls, and limestones ranging from the Pliocene to the Oligocene form the upper portion of the sediments. In the eastern part around Lakes Entrance, these beds rest on a floor of granite and old sedimentary rocks. To the west towards Sale and Morwell they are underlain by fresh-water sediments of Jurassic age containing enormous thicknesses of brown coal. The beds generally dip seawards at very low angles. No well-defined structures have been found save in the western portion of the basin. Most of the geological work has been done by officers of the Victorian Geological Survey.

Small quantities of oil have been found in shallow bores, rarely exceeding 1500 ft, sunk in the eastern part of the basin. The discovery well was drilled in 1924 near Lake Bunga, 6 miles to the northeast of Lakes Entrance. The oil occurs in a soft glauconitic sand at the base of the Oligocene. It is produced as an emulsion, and is usually accompanied by considerable volumes of water.

Between 1924 and the present day, at least fifty wells have been drilled in the eastern part of the basin by small companies holding small areas. Fifty other wells have been drilled jointly by Commonwealth and State Governments. Some oil was present in two-thirds of the wells drilled by private enterprise: the remaining wells were dry.

Very few showings of oil were reported in connexion with the wells drilled by the two Governments, but these were distributed over a very wide area, and many of them were drilled to secure geological information over the East Gippsland district as a whole. A government bore put down 2 miles east of Lakes Entrance in 1941 drilled through 40 feet of glauconitic sand into metamorphic rocks at 1244 ft, but found no trace of oil. According to an official report [2, pp. 36–7]: "The oil production has varied, that from

one of the government bores being approximately a pint of oil daily, while according to returns submitted by the companies concerned, their production has ranged from 1 to 50 gallons per day, and in one instance a much higher return was shown." Further : " It should be noted that although yields of a specific quantity (ranging from 1 to 50 gallons of oil per day) were reported in many instances as having been obtained, these figures have not been included as no uniform methods of estimation were followed."

The only company in the Lakes Entrance area which has made any noteworthy attempt to produce oil on a commercial scale is the Austral Oil Drilling Syndicate, and small quantities of oil, insufficient to pay for working expenses, have been sold by this syndicate from time to time. When Victoria amended its legislation governing the search for oil in 1940, the syndicate consolidated the various holdings around Lakes Entrance with the object of obtaining increased production.

In July 1941 the Commonwealth Government brought Leo Ranney from America to advise as to whether increased production could be obtained from the area around Lakes Entrance. Ranney was said to be the inventor of a process for drilling horizontally through an oil-bearing stratum, as well as of the machinery to accomplish this. To operate the method, a mining shaft has to be sunk to the oil-bearing sand and a chamber constructed in this to house the drilling plant.

After spending a few days at Lakes Entrance, Ranney reported that greatly increased production could be obtained by the use of his methods. He claimed that at least twenty holes radiating from the one chamber could be forced through the sand for a distance of half a mile from this centre, and that 400 acres of sand could be drained into a sump at the bottom of the shaft.

In September 1941, the Commonwealth and Victorian Governments lent £50,000 to the Austral Oil Drilling Syndicate for the purpose of shaft sinking in connexion with the Ranney plan. Shaft sinking proceeded very slowly and, in 1942, the Commonwealth Government decided to resume work in the Lakes Entrance area under National Security Regulations and to operate the Ranney project as a Government enterprise. Finance was to be provided as follows :—

Commonwealth Government . . .	£112,500
Victorian Government	37,500
Total	£150,000

Three years later (February 1945) the shaft was still unfinished, and this amount had been increased to £200,000 both governments increasing their commitments *pro rata*. By September that year, doubt was being expressed by the two Governments concerning the project. The engineer in charge of operations returned from California, where he had inspected work being done by Ranney's plant and methods. He reported against continuance of the project at Lakes Entrance, and work was suspended.

A résumé of the operations carried out at Lakes Entrance up to the end of February 1945 while the Commonwealth and Victorian Governments controlled the project was given by the Premier of Victoria in a statement to the House.[3] The points of importance were :—

A circular shaft was carried to 1156 *ft; a smaller timbered shaft within the concrete shaft was carried to* 1204 *ft. A winze reached the depth of* 1212 *ft,* 130 *ft of horizontal test drilling was done. The quantity of oil obtained per foot averaged less than a quarter of a pint per* 24*-hour period. Tests were conducted over periods ranging from one week to four weeks. The realizable value had been ascertained with a view to their disposal.*

Subsequently, the properties and equipment were handed back to the Austral Oil Drilling Syndicate. In September 1946 the directors of the Syndicate registered a company—Lakes Oil Ltd.—with a nominal capital of £200,000 with the object of carrying out horizontal drilling and other development at Lakes Entrance from the stage at which Government operations ceased. The nominal capital was increased to £1,000,000 early in 1949, and the directors reported that between 175 and 250 barrels of oil were being produced monthly. In a later statement (December 1949), it was claimed that 500 barrels of oil were in storage and that 750 barrels had been sold. It was admitted that production was insufficient to pay operating costs.

Although some drilling for oil has been done elsewhere in Victoria from time to time, notably at Torquay, near Geelong, and in the coastal area near the South Australian border to the west, none is worthy of mention with the exception of a test drilled jointly by Commonwealth and State Governments near Nelson. This test was drilled to 7305 ft between 1941 and 1946 in a narrow basin of Tertiary sediments which crosses the border into South Australia. The official view of the Victorian Geological Survey is that the hole was still in Tertiary sediments when drilling ceased.

In January 1950 it was announced that geological and geophysical surveys were to be carried out in this area by officers of the Commonwealth Bureau of Mineral Resources.

Tasmania

Tasmania has been more interested in the development of its oil-shale deposits than in prospecting for flow oil. Two shallow bores were, however, drilled for oil by a small local company in 1914–15. One was at Port Davey in the extreme southwest of the Island: the rocks belonged to an ancient complex of sedimentaries intruded by granite. The second was on the east coast of Bruny Island, southeast of Hobart. The well penetrated a few feet of Permian sediments, passed into a sill of basalt, and was closed down. In neither case were any traces of oil or gas met with.

New South Wales

It may be due, in part, to the vast coal resources and rich oil shale deposits of this state that less work has been done in seeking for flow oil than in other states of the Australian Commonwealth, with the exception of Tasmania. Excluding the work done in the past three years by the Frome–Broken Hill Company, a subsidiary formed by a combination of the Zinc Corporation, D'Arcy Exploration, and the Vacuum Oil Company, to investigate the oil possibilities of the Mesozoic and possibly older sediments of the Great Artesian Basin of Central Australia, no major company has undertaken prospecting for oil in New South Wales. The work done by the

Frome–Broken Hill Co. was confined to that part of the Great Artesian Basin which extends into western New South Wales. Authority to explore was taken up by the company in 1947. The area taken up was in the northwest corner of the state on the borders of Queensland and South Australia and covered 11,000 square miles. This formed part of a compact block of 85,200 square miles, the greater part of which, 49,000 square miles, was in the northern part of South Australia, while a further 25,000 square miles was in southwestern Queensland. The work has now ceased, and all areas have been abandoned. Further details of this work are given under South Australia.

The earlier prospecting for oil was confined almost entirely to a trough-like depression filled with sedimentary rocks which extends from a few miles south of Sydney, northwards to beyond the Hunter River. Sandstones and shales of Triassic age cover much of the central parts of the basin: they overlie Permian coal measures and marine deposits on the margins; Carboniferous and Devonian sediments outcrop in some areas. The great coalfields of New South Wales—Sydney, Newcastle, Maitland, and the southern and western coalfields all lie within this basin. The sediments within the basin are gently folded, and numerous closed structures have been found by geologists working within the area. No surface evidences of oil are known, but some gas, methane as a rule, has been found in wells and borings for coal in this region. In a very few cases, however, higher homologues have been present and the gas has been "wet." "Wet" gas was found in the old Balmain coal-mine situated on Sydney harbour and near the axis of the trough of the Sydney Basin. Test drilling showed that the coal measures were underlain by Permian marine strata. Attempts to exploit this gas commercially were unsuccessful, and the operating company closed down in 1949.

Between the two world wars, several small companies with small capital took up small concession areas on some of these structures, but with few exceptions little drilling was done, and the results are not worth recording. The only company to take up the search in New South Wales on a regional scale was Oil Search Ltd. of Sydney. Under the leadership of experienced American oil geologists, this company embarked on an Australia-wide campaign in 1930. Activities of the company covered parts of Queensland, Victoria, and Western Australia, as well as New South Wales. Work was commenced also in the Mandated Territory of New Guinea and, later, spread to Papua.

In New South Wales between 1935 and 1937 a test well was drilled with cable tools at Mulgoa on the Nepean River about 40 miles to the west of Sydney. The structure was a fold in the Hawkesbury Sandstone (Triassic). Drilling ended in Permian coal measures at 2648 ft. Showings of gas were recorded, but no oil. The well was abandoned.

Oil Search geologists had located another structure in Triassic rocks at Kulnura just over 50 miles almost due north of Sydney, and a well was drilled on this between 1935 and 1938. It was carried to 6293 ft, and ended in Permian marine sediments. There is controversy as to whether these represented the Upper or Lower Marine Stages of New South Wales. Some gas showings were met with just above coal measures. No oil was reported.

No drilling for oil of any consequence has been done in the State since 1938, when Oil Search Ltd. ceased to be interested in the search for oil on the mainland of Australia, and joined with D'Arcy Exploration and Vacuum Oil to form the Australasian Petroleum Company for the purpose of carrying out work in New Guinea Territories.

QUEENSLAND

During the past sixty-three years, some 5000 wells have been sunk in the Queensland portion of Australia's Great Artesian Basin to augment the water supplies of a region in which surface waters are scanty and seasonal. One of these wells, at Springleigh in Western Queensland, was drilled to a depth of over 7000 ft in 1921, and was reputed to be the deepest artesian bore in the world. It is thought to have been drilled throughout in the Mesozoic sediments of the Basin, and had not reached bed-rock when drilling ceased.

Showings of gas were met with in many of these wells, but in most cases they were methane. In a few wells, as at Springleigh, Ruthven, Longreach, all in the same district, small quantities of heavy oil came to the surface along with artesian water, which reached the surface at only a few degrees below boiling point. On cooling, due to a high content of paraffin wax, it turned to a light brown, waxy or vaseline-like substance.

Little interest was taken in these occurrences until developments in the area around the town of Roma in Central Queensland led to what can only be described as a minor "oil boom" and, as is usual in such cases, the floating of many companies.

In the year 1900 the town authority drilled its second well for water on Hospital Hill, which is immediately west of the town and 1020 ft above sea-level. Artesian water was struck at about 1700 ft. With the object of increasing the flow, the well was deepened and at 3683 ft met with natural gas. A flow of over 39,000 cu. ft. per day was measured. Nothing was done for four years, when it was noted that the flow had increased to 70,000 cu. ft. a day. A gasometer was erected and pipes were laid through the town. In 1906 the streets were lit for ten days, and then the flow suddenly diminished and the scheme was abandoned. Such a strange phenomenon in Australia excited public interest. Hopes of finding oil at Roma rose high. A company was formed, and with government assistance, another well was drilled within 250 ft of the gas well in 1908. Gas again came in at 3702 ft; it caught fire, burned for six weeks, and was extinguished with difficulty. This was the best advertisement Roma ever had.

The Queensland Government consulted leading authorities in Great Britain and the United States, and since all that was known was that the wells had been drilled through marine Cretaceous and lacustrine Jurassic sediments to a depth of over 3000 ft without meeting with bed-rock, it was assumed that there was still a considerable thickness of sedimentary rocks below the horizon from which the gas was emanating. Most of the advice obtained favoured further drilling. In 1916 the Queensland government proclaimed an area around Roma as an oil reserve and decided to drill another well, this time with the object of drilling through the gas sand and of testing for oil the deeper sediments believed to exist. The well was not completed until 1930, when gas was met with between 3624

and 3700 ft. It was found to be " wet " when tested; 1·22 pints of petrol per 1000 cu ft were obtained by means of a small absorption plant. Water broke in, however, and the well was abandoned. The government reduced the area held as an oil reserve to an area of 60 miles square around the Roma well, and in 1923 amended the legislation governing the search for oil to provide for prospecting permits up to 10,000 acres, and otherwise encouraged private enterprise. One company was granted a licence to drill within the reserved area at Oralla, 25 miles north of Roma. Three holes were drilled, and showings of oil and gas were reported, but the wells were abandoned in 1925. Granite basement was found in two of these wells.

In 1926 the reservation was thrown open, and several companies were formed to drill in the Roma area. By 1929 thirty tests, deep by current standards, had been drilled or were in process of drilling in the Roma area. Another gas well had been drilled, and in this case salt water accompanied the gas at 3703 ft, whereas higher waters were fresh. The gas was flowed under control at a pressure of 350 pounds to the square inch. Analysis showed :—

	per cent
CO_2	1·5
CO	5·8
CH_4	74·6
Ethane and higher paraffin hydrocarbons	9·8
Benzene series	5·0
Olefin series	1·5
Nitrogen and residual gases	3·4

Petrol or natural gasoline content was 2·6 pints per 1000 cu. ft. This was recovered by a gas-absorption plant erected on Hospital Hill. Sales were made locally, and some as far away as Brisbane.

Some of these wells bottomed on granite bed-rock, others on hard and somewhat metamorphosed shales and quartzitic grits of unknown age. The results were in all cases disappointing. About this time the Elbof Geophysical Company made gravity surveys of parts of the area, but the reports were not made public.

The first actual production of oil in the Roma area was made in 1930 by the Roma Blocks Oil Company. This company drilled a well to 3447 ft near Mt Bassett about 13 miles to the northeast of Roma. Oil accompanied by brackish water was found in arkosic grit just above a bed-rock of granite; petrol production was at the rate of 10 gallons a day. It was a dark, reddish-brown crude with a paraffin base and of good quality. When this well was re-opened by Dr Wade seven years later, production of oil was at exactly the same rate as in 1930.

In the early 1930s activities had spread to Blythedale, 12 miles to the east of Roma. Here five wells were drilled to bed-rock by different companies. The deepest was in granite at 4130 ft. Oil and gas were found just above bed-rock in these wells, but no production of importance was obtained, and the area was abandoned. By 1932 £800,000 had been spent on the search for oil in the Roma area, and about 110,000 ft of drilling done. The positive results were the production of 30,000 gallons of natural gasoline from the wells on Hospital Hill and a few hundred gallons of oil from wells at Mt Bassett and Blythedale.

Oil Search Ltd. took up the search in the Roma area in 1933 with a

belief that failure had been due to inadequate detailed geological investigation to locate favourable structural conditions. The company proceeded to drill a large number of shallow wells in the search for suitable structure, and a well was drilled at Warooby, 8 miles east of Roma, but the results were no better than elsewhere.

In 1934 the government, by proclamation, exempted from licence or lease, a rectangular area of 40,000 square miles based on an east–west line running through Roma and extending northwards. The government laid down stringent conditions under which authorities to prospect in this area would be granted, and such authorities were to be non-exclusive. In the meantime Oil Search had engaged the services of two well-known American petroleum geologists, D. Dale Condit and Dr Frank Reeves. The company then obtained authority to prospect over the reserved area, and Dr Frank Reeves took charge of the work. After studying the problem, Condit and Reeves formulated new ideas with regard to the origin of the oil and gas at Roma. It was believed that it had originated in the Permian rocks of the southern extension of the Bowen Syncline which lay to the north and is divided from the Great Artesian Basin to the west by a ridge of Palæozoic sediments and other rocks. The oil was believed to have migrated towards this ridge. Basing his work on this theory, Reeves moved away to the north of the Roma district and began a careful geological examination of the country between this and Springsure, 220 miles north of Roma. Several anticlines were mapped in Permian or Lower Triassic rocks, and the Oil Search Company brought in percussion rigs and began to drill at Hutton Creek and Arcadia in 1935, some 60 and 80 miles north of Roma respectively. Some gas was met with in Permian sediments in the Hutton Creek bore, but the biggest flows of gas were from the Arcadia well. Gas increased in volume between 2560 and 2620 ft. The volume of gas escaping at the lower depth was measured at over 4,000,000 cu. ft. a day at a pressure of over 400 pounds to the square inch. The beds were marine shales and thin sandstones of Permian age. Some very light showings of oil had also been noted above the gas zone. The gas was a "wet" gas, but was unusual in that it consisted of 80 per cent carbon dioxide.

At between 3000 and 4000 ft, drilling operations were suspended at both sites; the thickness of Permian sediments was greater than expected and the drilling plant was not capable of drilling to greater depths. At this time an Oil Advisory Committee had been constituted by the Commonwealth Government. Through the offices of this committee, heavy-duty rotary drilling plant was lent to Oil Search Ltd. and financial assistance was provided by the government to enable the two wells to be deepened. The hole at Hutton Creek was carried to 4688 ft, but nothing was found to warrant further drilling and the well was abandoned in 1938. At Arcadia drilling continued mostly in dark shales of Permian age to 6025 ft. The hole, however, was not in good shape, and operations were suspended in December 1939. After Oil Search joined forces with D'Arcy Exploration and Vacuum Oil Company to embark on widespread investigations in New Guinea, the company decided in 1939 to abandon further work in Australia.

After a lapse of several years, the Roma Blocks Oil Company decided to drill again in the Mt Bassett area, 12 to 13 miles to the northeast of

Roma. The No. 1 well of this company had produced more oil than all the other wells drilled in the Roma area put together, although production only amounted to 10 gallons of oil and a much larger quantity of saline water per day. The area around the well was carefully mapped in detail, the surface rocks being marine Cretaceous. The Commonwealth Government assisted in the financing of three wells drilled to bed-rock of granite between 1936 and 1939, but though oil-impregnated grits were found above the basement rocks, production was insufficient to warrant further drilling.

After forty years of persistent effort to find oil in Queensland had met with equally persistent failure, the State Government decided late in 1939 to amend the law governing the search for oil in Queensland, so as to encourage the major oil companies to take up the task on a larger scale. In November 1939 Parliament amended the Act governing the search for petroleum, and the Shell Company secured rights to explore 164,000 square miles of Central Queensland. Late in 1940, the Superior Oil Company of California took up a large area in Western Queensland, but surrendered their holding after an examination had been made by American geologists.

The Shell Company formed a subsidiary, Shell (Queensland) Development Pty. Ltd., to take the responsibility of carrying out investigations in its area. Geologists carried out reconnaissances over the whole region. Geophysicists, using gravity meters, covered a large portion of it, and an equally large portion was photographed from the air. For these purposes, more accurate topographical maps than were available were required, so the surveyors triangulated and mapped all areas considered to be of importance. As work progressed, several good geological structures were found and mapped in detail. By the time the United States was drawn into the war at the end of 1941, 250,000 square miles of country had been reconnoitred by geologists; 12,600 square miles closely examined; geophysical investigations covered 200,000 square miles; 10,000 square miles had been photographed from the air; and 3280 water and other wells had been studied at a cost of nearly £150,000. Since geological features, like all other natural phenomena, ignore the mathematical straight lines which constitute man-made boundaries, geologists and geophysicists found it necessary to go beyond the limits of the company's holdings to obtain essential data.

Owing to the difficulties which had arisen with regard to securing plant for the drilling of a deep test and to other circumstances arising out of the war, work was suspended early in 1943.

The end of the war led to resumption of operations in 1946. This time the main objective was the selection of a site for a deep test. By this time the area held under permit to explore had been narrowed down to 56,000 square miles, and several structures were held under Petroleum Prospecting Permits. It was considered necessary to check at depth the configuration and closure of these structures as estimated from surface indications. A Failing 2500 portable rotary outfit was secured from the United States and a campaign of " slim-hole " drilling was carried out on structures considered to be most promising. At the same time further geological work was done in close detail. By September 1949 the site for a deep test had been selected on an anticline at Morella. A rotary drilling outfit capable of drilling to a depth of 10,000 ft or more, most of it made in

the United Kingdom, was obtained and transported to the drilling site. All preparations to drill were well advanced by January 1950, and drilling commenced in April. The greater part of £1,000,000 had already been spent by the Shell Company on this venture. The results obtained by the drilling of this well after years of patient and efficient investigation will be conned with more than usual interest.

Drilling for oil has been carried out in many localities of Queensland far removed from Roma. Most of these, however, were speculative enterprises undertaken by small local companies, and no results of importance have been recorded. They have contributed little to the more serious efforts to find oil which have been dealt with above.

South Australia

The search for oil in South Australia was based on two unusual occurrences. First was the finding of bituminous fragments on the coasts of the state from the Victorian border in the southeast to the head of the Great Australian Bight to the west. Actually they have been found at places between this and Cape Leeuwin at the southwestern extremity of the continent, as well as to the southeast along the coasts of Victoria. Pieces weighing as much as a hundredweight have, in some instances, been found lying between tide levels on the shores of the state. It is not disputed that they have been thrown up by the sea, but a belief developed that they originated in seepages from outcrops in the continental shelf and that the beds from which the bitumen came might extend landwards under the continental margins.

The second was the occurrence of a leathery, somewhat elastic material on the floors of salt pans between the old sand dunes of the Coorong in the southeast of the state and on salt flats on Kangaroo Island. This material is readily inflammable, burning with a smoky flame, while from it a fluid resembling a paraffin-base crude oil can be obtained by dry distillation. This substance, called Coorongite, was thought by many to have originated from seepages of oil. Scientific examination indicated that it was formed by species of algæ.

On the strength of these occurrences, areas were taken up and small companies formed between 1912 and 1916 to drill for oil. Many such areas were underlain by granite, metamorphic rocks, pre-Cambrian to Cambrian sediments, and the like. Drilling was done on Eyres and Yorke Peninsulas and in the southeast of the state from the sandy waste of the Coorong to the Glenelg River on the Victorian. No well-authenticated showings of oil or gas resulted from all this activity.

Between the two wars the only area in which interest was shown was in the far southeast near Mount Gambier. The Tertiary basin already referred to as existing in the western coastal area of Victoria extends into this part of South Australia. One or two wells were drilled in the 1920s, but results were negative.

There are, however, well-authenticated reports of the occurrence of oil and inflammable gas in South Australia. Free oil was found in core samples from a diamond-drill hole put down in 1890 for the purpose of investigating the coal seams present in the Leigh's Creek Coal Basin which is between 400 and 500 miles north of Adelaide. The strata are of Jurassic

age, and the hole was carried to bed-rock at 1900 ft in the hope of obtaining a flow. The results were negative. Since the second world war, this basin has been extensively drilled, and has been opened up to supply coal to Adelaide. No further discoveries of oil have been reported.

In 1908 inflammable gas was reported to have been met with in bores put down for water at Coonanna and Yandama near Lake Frome in the northeastern part of the State. The area in which both wells are situated is in the South Australian portion of the Great Artesian Basin. Inflammable gas is of common occurrence in the artesian and sub-artesian wells of the Queensland part of the Basin.

In 1946 the Broken Hill Mining Company became interested in this area as a possible source of supplies of natural gas which could be piped to the great mines which lie over the border in New South Wales. Authority to prospect over an area of 7500 miles was obtained, and geological investigations were commenced.

In 1947 the Zinc Corporation, the senior member of the Broken Hill group, joined forces with D'Arcy Exploration and the Vacuum Oil Company with the object of instituting a widely spread search for oil in Australia. Authorities to prospect over a large part of the Great Artesian Basin, comprising parts of South Australia, New South Wales, and Queensland, were obtained. Arrangements were also made to prospect for oil over extensive areas in Western Australia and the Northern Territory. In South Australia, authorities covered an area of approximately 50,000 square miles in the northeastern corner of the State. A subsidiary company, the Frome–Broken Hill Company, was formed with a capital of £150,000. Geological and geophysical surveys were carried out, the latter including use of the "flying magnetometer." Much of this region was photographed from the air, and scout drilling was done with American light portable rotary drilling outfits. Later, a recommendation was made to test for oil the Jurassic or even older rocks below the water-bearing horizons of the Great Artesian Basin by drilling near Lake Eyre. A test well was therefore drilled to bed-rock at Kopperamanna late in 1948 with negative results. In February 1949 it was reported that the company had abandoned its search for oil in South Australia.

Western Australia

Western Australia is unique in the fact that it is the only state in which a search for oil has been based on a genuine occurrence of oil at the surface. The vesicles of a basalt underlying fossiliferous Cambrian limestones and shales at Texas out-station near the junction of the Ord and Negri Rivers in the East Kimberley district are filled with heavy, viscous, asphaltic oil. The discovery of this oil-bearing basalt by Walter Okes in 1920 led to the formation of the Okes–Durack Oil Company. A site was selected near the Ord River (approx 17° 20′ lat., 128° 50′ long.), and a test well was drilled through a sequence of Cambrian limestones and shales to a depth of 1196 ft. At this depth basalt was met with, and the well was abandoned in 1924. No showings of oil or gas were recorded.

Soon after Okes made his discovery, showings of oil were found in limestones and shales of Devonian age in a well drilled for water by Harry Price in 1922 in the Rough Range near Christmas Creek in the West

Kimberley district (approx 18° 40′ lat., 125° 55′ long.). As soon as news was received of the presence of oil in this well, a senior geologist was sent to supervise further drilling, and samples were sent for testing to the Government analyst in Perth. The hole was carried to 1008 ft. Showings of oil were found in two other wells drilled nearby; both finished in massive Devonian limestones. No production was obtained from any of these wells.

The Freney Kimberley Oil Company was formed in Perth to investigate an area of 30,000 square miles in the West Kimberley district for oil. Geological reconnaissances were conducted over wide areas, and a test well was drilled with cable tools on an anticlinal structure at Mount Wynne (approx 18° 5′ lat., 124° 40′ long.) in 1923. The Mount Wynne well ended in Permian sandstones at 2000 ft. The only evidence of oil found consisted of a few blobs of bitumen (up to 1 inch diameter) in massive Permian sandstones.

Dr Arthur Wade made an examination of the area on behalf of the Commonwealth Government in 1924.[14] The company then transferred its attention to a much faulted anticlinal structure in Permian sediments at the Poole Range (approx 19° 10′ lat., 125° 30′ long.), where further tests were drilled between 1925 and 1930. The deepest of these went to 3264 ft, and though showings of oil were reported, no oil was produced and drilling was abandoned.

In the years from 1934 to 1936 Dr Wade investigated the area for the Company in more detail. Some of the structures found were mapped in detail on a scale of 8 inches to 1 mile and 4 inches to 1 mile, while reconnaissance mapping was done on a scale of 1 inch to 1 mile. Some of the maps were printed and published by the Commonwealth Government in 1937.[23]

In 1940 the West Australian Government amended its Petroleum Act. The Freney Kimberley dropped its Permit to Explore for oil over 30,000 square miles and took up Licences to Prospect over three smaller structure areas, together covering 450 square miles. At the same time Caltex (Standard of California and the Texas Oil Company) took up a Permit to Explore over the greater area and commenced further geological investigations.

The Commonwealth Government lent a heavy-duty rotary drilling outfit to the Freney Kimberley Company, which commenced drilling in Permian sediments at a site on the Nerrima Dome (approx 18° 30′ lat., 124° 20′ long.). When a depth of 4271 ft had been reached, drilling was suspended by order of the Commonwealth Government in 1943, and was not resumed until 1949. Drilling difficulties encountered in cleaning out and reaming the hole have again led to suspension of work until further equipment is available.

Simultaneously with the suspension of drilling by the Freney Kimberley Company in 1943, the geological investigations of Caltex came to an end, but it was announced that these would be continued as soon as circumstances allowed. After the war, Caltex did not renew its investigations in the West Kimberley district, but in 1947 a combination of major interests comprising D'Arcy Exploration, Vacuum Oil Company, and the Zinc Corporation secured rights to explore for oil over the area formerly held by Caltex, as

well as over an area around the small seaport of Wyndham and extending southwards to take in the lower basin of the River Ord. A subsidiary company, the Bonaparte Gulf Oil Company, was formed to conduct investigations. Dr Frank Reeves, assisted by Commonwealth and State geologists, carried out extensive reconnaissance surveys both from the air and on the ground. In 1949 Dr Reeves submitted an unfavourable report, and the companies abandoned all interests in Western Australia.

In 1924 the American geologist, F. G. Clapp, discovered anticlinal folding in a deep basin of Tertiary sedimentation at Northwest Cape, the extreme western point of Western Australia. In a series of papers he expressed highly favourable opinions of the oil possibilities of this area. Subsequent work revealed that this Tertiary basin was part of a larger basin in which was a thick series of sedimentary deposits ranging from Tertiary down to Permian, and possibly older rocks. This was called the Northwest Basin.

Oil Search Ltd. of Sydney acquired Permits to Explore over the area comprising the Northwest Basin. American and Australian geologists mapped the area in the years 1934–35 and found at least seven anticlinal structures. The most impressive of these forms the promontory which terminates at its northern end in Northwest Cape. The reports submitted confirmed Clapp's opinions. No drilling was done. The financial and technical resources of Oil Search Ltd. were directed towards the finding of oil in New Guinea when the company entered into an association with D'Arcy Exploration and Vacuum Oil in 1938. No further work was done in the Northwest Basin.

In 1948, however, the Australian Motorists Petrol Company, now known as Ampol, joined with the Richfield Oil Corporation of California to investigate the oil possibilities of coastal strips extending from the Leeuwin on the south to the northernmost part of the state. Aerial and geological surveys were carried out under the direction of an American geologist E. Craig, lent by the Richfield Corporation. Subsequently, Oil Search's holdings in the Northwest Basin were taken over by Ampol, and another intensive study of the area was made by Ampol, Commonwealth Government, and State Government geologists. This work is still proceeding. In the meantime, however, Craig has issued highly optimistic reports which have been supported by statements issued by the Commonwealth Bureau of Mineral Resources. Richfield withdrew from the venture in 1949, but the Ampol Company has announced that it is the intention to commence deep drilling with modern rotary plant as soon as possible in 1950.

Other areas in Western Australia which have been prospected for oil include a belt of Permian sediments between the Gascoyne and Murchison Rivers, which is the southern extension of the Northwest Basin, an outlying Permian area on the Irwin River which is really a further southerly extension of the same belt, and Recent to Late Tertiary deposits which are found in the fiord-like inlets on the south coast of the state. These form only a thin cover over schists, granites, and other old rocks, but they contain thin seams of black carbonaceous matter which, being unlike a true coal, have been regarded by some prospectors as evidences of oil.

Northern Territory

Heavy asphaltic oil occurs in the vesicles of a basalt associated with Cambrian and older sediments at the Waggon Lagoon near the Roper River.[16, p. 37]

Flat disks up to 4 inches diameter of very hard carbonaceous matter which has a jet-like appearance when fractured occur in shales of Proterozoic age on Elcho Island. They are now almost pure carbon and may represent bands of bitumen, coal, or even an original oil content. They are the remnants of original constituents of the rocks after hundreds of millions of years of slow metamorphic changes.

In 1924 a small company drilled a shallow test for oil in these Proterozoic rocks. Nothing of consequence was found.

The Bonaparte Gulf Company (see South Australia) extended its activities across the borders of Western Australia into Northern Territory. The company acquired rights to explore a tract of country along the border between latitudes 12° 0′ and 17° 0′. Within this area are two Permian sedimentary basins overlying Proterozoic quartzite and shales: one between the mouth of the Daly River and the mouths of the Fitzmaurice and Victoria Rivers, and the other farther south in the Burt Range.

After geological reconnaissances by Dr Frank Reeves and assistants, this area was dropped in 1949. Part of it was taken up later in the same year by the Australian Motorists Petrol Company (Ampol Ltd.) who extended the area to be prospected in a southerly direction to lat. 20° 0′. So far as is known, no serious work has been done in this area by Ampol.

Territory of Papua

The presence of seepages of oil in the coastal area around the head of the Gulf of Papua has been known for at least sixty years, since mention is made of them in a report by A. Gibb Maitland in 1891. Reference is also made to them by J. E. Carne, who made geological reconnaissances in the Territory of Papua on behalf of the Commonwealth Government about ten years later. Interest became active in 1912, when areas in the region between the Purari and Vailala Rivers were pegged by different parties who hoped to obtain permits for their development. The Commonwealth Government of that period decided that the possible development of oilfields in Papua was of such national importance that the Government would investigate the possibilities of the Territory on its own behalf, and no concessions were granted.

In 1913 Dr Arthur Wade was brought out from England to undertake the preliminary exploration work. Before Dr Wade's arrival, however, some drilling with light percussion plant was commenced at Upoia on the Vailala River. Upoia was selected because several small seepages of oil and some "blows" of natural gas had been noted on or near the riverbanks in this area. A good showing of light oil was found in one of the holes drilled at a depth of about 190 ft. With this encouragement a heavier cable-tool outfit with light-steel-framed derrick was imported from Australia, and attempts to drill to greater depths began in 1914.

In 1913–14 Dr Wade, assisted by Evan Stanley, the Government geologist, and two junior geologists and surveyors, made a reconnaissance geological

survey from the Kikori River to Port Moresby and traversed the Territory from the mouth of the Vailala River to its headwaters and across into what was then German New Guinea. This was the first crossing of the Territory to the Main Ranges made in this western part of Papua, though earlier expeditions had explored the upper reaches of the Purari and Kikori Rivers. Much of the country was mapped, a few areas in more or less detail, and a report was submitted to and published by the Commonwealth Government.[26]

After war broke out in 1914 the Commonwealth Government decided to push ahead with efforts to find oil in Papua. In 1915 Dr Wade was asked to take charge of this work. Geological surveys were made in more detail of the country around Upoia, on the coast at Hohoro, and of other areas between the Purari River and Cape Possession. Drilling with cable-tools continued at Upoia on the west basin of the Vailala River and commenced at Akauda on the east bank. More oil was found at shallow depth at Upoia, and a blowout of high-pressure gas occurred at a depth of about 1500 ft. Although no serious attempt was made to produce oil from the shallow horizons, between 4000 and 5000 gallons were accumulated, some was used on the field, some was sold locally for use in motor launches, and a 40-gallon drum was taken to Melbourne.

The oil was of a pale straw colour, and had a specific gravity of 0·78. At low temperatures clear white paraffin wax separated from it. After filtering, several gallons were put in the tank of the Prime Minister's car in Melbourne, and no trouble was experienced in starting and running the car around the city.

On taking over the management in 1915, Dr Wade ordered a complete rotary drilling outfit, but owing to war conditions and slow delivery, drilling by rotary did not commence till 1918. Attempts were made to drill to depth at three sites, but flowing muds at various depths hampered progress, and the deepest hole was just over 2000 ft.

Before Mr Hughes, as Prime Minister, went to the Peace Conference in 1918, he discussed problems connected with the search for oil in Papua with Dr Wade. Dr Wade advised that the whole project should be handed over to one of the major oil companies. Mr Hughes thought that the British Government might be induced to enter into partnership with the Australian Government to carry on the work. In London Mr Hughes prevailed upon the British Government to enter into such a partnership on a basis which was limited as to the financial commitment and on condition that the Anglo-Persian Oil Company undertook management of the work on behalf of the two Governments. Dr Wade handed over to officers of the Anglo-Persian Company late in 1919.

Further work on the Vailala River was abandoned, and geological surveys were commenced around the village of Popo near Cape Possession. Several structures were mapped, and drilling was commenced on a broken anticline near Popo. Several wells were drilled, but troubles with flowing muds, similar to those experienced at Upoia, led to the wells being abandoned before reaching any worthwhile objective. After the geologists of the company had submitted an adverse report in 1924, further search for oil on behalf of the Commonwealth Government in Papua was abandoned, and it was made known that the field was open to private enterprise.

Small Australian companies took up the search. The Oriomo Company did some work in the far southwest of Papua west of the Fly River. Another company drilled without success on an anticline at Hohoro just west of the mouth of the Vailala River and near the village of Orokolo.

In 1929 Oil Search Ltd. was formed in Sydney and incorporated in Papua. The company acquired assets of the Oriomo Company and became interested in exploration for oil in Papua.

In 1936 the Commonwealth Government amended the ordinances governing the search for oil in Papua at the same time as the ordinances were redrawn in the Mandated Territory of New Guinea. Oil Search then took up an area of 12,000 square miles of country in a strip which extended from Cape Possession to the Purari River, and embarked on geological investigations.

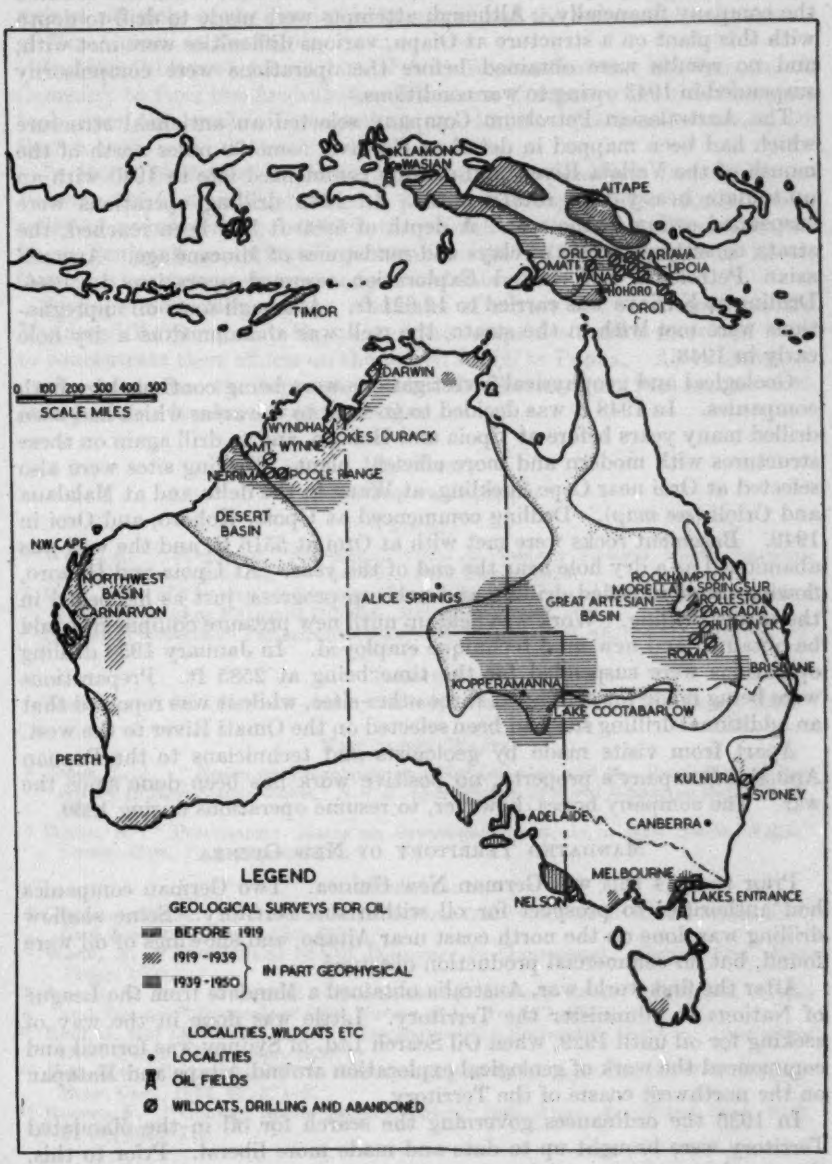
About the same time, two of the major oil companies became interested in exploring for oil in Papua. The Papua Oil Development Co. Ltd., a subsidiary of the Shell Company, took up a block around the mouth and lower reaches of the Fly River and extending to the border of Dutch New Guinea in the far southwest of Papua, as well as part of the combined deltas of the Turama, Omati, Kikori, and Purari Rivers. The Island Exploration Company, a subsidiary of the Vacuum Oil Company, obtained a permit to explore for oil over an area lying to the west of the Oil Search block and extending westwards to Omati River. In addition, the Papuan Apinaipi Petroleum Company acquired rights to prospect over an area of 75 square miles near Cape Possession.

Geological and aerial surveys were commenced on all areas. Geophysical investigations were also carried out by the Papua Oil Development Company and Island Exploration Company, both of which had headquarters at Daru in Western Papua. Scout drilling with light portable rotary plant was done by Papua Oil Development. Sediments other than recent delta and river deposits consisted of a thick sequence of Tertiary clays and mudstones, with occasional bands of argillaceous sandstone and thin limestones. Underlying these in the western part of the area, massive chalk-like limestones were met with at depth.

To encourage the operating companies in what proved to be expensive and exhausting work, the Petroleum Ordinances were again amended in 1938. Papua Oil Development, however, abandoned the search because of unfavourable geological conditions. Island Exploration extended its holdings far inland to the headquarters of the Strickland and Fly Rivers.

Oil Search Ltd. was beginning to feel that its future programme was beyond its resources and entered into negotiations with the Anglo-Iranian Company (D'Arcy Exploration Company) and Vacuum Oil Company to obtain greater financial and technical support. A subsidiary company, the Australasian Petroleum Co. Pty. Ltd., was formed by the three interested concerns. The nominal capital has expanded until it is now (1950) £10,000,000, of which the two senior partners hold 40 per cent each and Oil Search Ltd. 20 per cent. The areas held by Oil Search in Papua and the Mandated Territory were taken over, and additional areas westwards to beyond the Kikori River were acquired—in all, about 10,000 square miles of territory.

The work of investigation was intensified in all branches and by all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SCALE MILES
WYNDHAM
MT. WYNNE
OKES DURACK
NERIMA
POOLE RANGE
DESERT BASIN
N.W. CAPE
NORTHWEST BASIN
CARNARVON
ALICE SPRINGS
GREAT ARTESIAN BASIN
ROCKHAMPTON
MORELLA
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companies after 1938. A rotary drilling outfit was lent to the Papuan Apinaipi Company by the Commonwealth Government, which also assisted the company financially. Although attempts were made to drill to depth with this plant on a structure at Oiapu, various difficulties were met with, and no results were obtained before the operations were compulsorily suspended in 1943 owing to war conditions.

The Australasian Petroleum Company selected an anticlinal structure which had been mapped in detail at Kariava, some 30 miles north of the mouth of the Vailala River, and drilling commenced late in 1940 with an up-to-date heavy-duty rotary outfit. In 1942 drilling operations were suspended owing to the war. A depth of 5800 ft had been reached, the strata consisting largely of clays and mudstones of Miocene age. Australasian Petroleum and Island Exploration resumed operations in 1946. Drilling at Kariava was carried to 12,621 ft. Although some oil impregnations were met with in the strata, the well was abandoned as a dry hole early in 1948.

Geological and geophysical investigations were being continued by both companies. In 1948 it was decided to go back to the areas which had been drilled many years before at Upoia and Hohoro, and to drill again on these structures with modern and more efficient plant. Drilling sites were also selected at Oroi near Cape Suckling, at Wana in the delta and at Malalaua and Orloli (*see map*). Drilling commenced at Upoia, Hohoro, and Oroi in 1949. Basement rocks were met with at Oroi at 5516 ft, and the well was abandoned as a dry hole near the end of the year. At Upoia and Hohoro, flowing muds impeded drilling and held up progress, just as happened in the earlier drilling. Work was held up until new pressure equipment could be obtained and new mud technique employed. In January 1950 drilling operations were suspended for the time being at 2585 ft. Preparations were being made for drilling at three other sites, while it was reported that an additional drilling site had been selected on the Omati River to the west.

Apart from visits made by geologists and technicians to the Papuan Apinaipi Company's property, no positive work has been done since the war. The company hopes, however, to resume operations during 1950.

Mandated Territory of New Guinea

Prior to 1914 this was German New Guinea. Two German companies had authorities to prospect for oil within the Territory. Some shallow drilling was done on the north coast near Aitape, and showings of oil were found, but no commercial production obtained.

After the first world war, Australia obtained a Mandate from the League of Nations to administer the Territory. Little was done in the way of seeking for oil until 1929, when Oil Search Ltd. of Sydney was formed and commenced the work of geological exploration around Aitape and Matapau on the northwest coasts of the Territory.

In 1936 the ordinances governing the search for oil in the Mandated Territory were brought up to date and made more liberal. Prior to this, the search was hampered by the comparatively small areas which could be taken up, and other restricting conditions. Under the new ordinances, Oil Search Ltd. acquired a permit to prospect over 13,000 square miles, taking in the lower part of the Sepic River Basin and extending westwards

to the border of Dutch New Guinea. A good deal of geological work was done in this area, especially on the Tertiary sediments lying between the axis of old rocks in the Torricilli Mountains and the mountainous backbone of New Guinea to the south.

In 1938 Oil Search joined with D'Arcy Exploration and the Vacuum Oil Company to form the Australasian Petroleum Company, and this Company took over the work of prospecting the 13,000 square miles which Oil Search held.

In 1937 The Island Exploration Company, a subsidiary formed by the Vacuum Oil Company, obtained a permit to prospect over 10,000 square miles of country lying between the mouth of the Sepic River and the Huon Peninsula and extending inland to the valley of the Ramu River. Geological surveys were made of parts of this region.

Seepages and other surface evidences of oil are not so common in the Mandated Territory as in Papua, and the companies tended more and more to concentrate their efforts on the search for oil in Papua. All exploratory work ceased when the Japanese invaded the Territory in 1942, and no work of importance has been done since then.

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Oilfield Exploration and Exploitation

Geology

2459. The classification of oil deposits. J. Czernikowski. *Nafta*, July 1950, **6**, 181–4; Aug. 1950, **6**, 212–15.—Economic classification of deposits is not adequate. Geological definition of a deposit speaks of a complex of permeable rocks containing hydrocarbons held by gravitational and capillary forces surrounded by non-permeable formations. Such rocks are mainly sandstone and limestone. Author discusses seventeen kinds of porosity. Gravitational forces make use of underground folds retaining the crude and underground waters which form a seal. Ten possibilities are discussed. Some combinations of the porosity and folds are more likely to hold crude oil than others, and to such combinations search should be directed. M. S.

2460. Photographic technique in petroleum exploration and drilling. B. Fleszar. *Nafta*, July 1950, **6**, 184–8.—Author describes briefly the method and advantages of "trimetrogon" aerial photography. In second part are given details of the deep-well camera and its short-comings. Several improvements are suggested. M. S.

2461. Poor-boy pool. D. H. Stormont. *Oil Gas J.*, 22.2.51, **49** (42), 128.—Current production from the Willow Springs field, 25 miles southeast of Bakersfield, California, is approx 3000 b.d. The field contains a number of pools, with pay depths varying from 400 to 1700 ft. The field, which trends northeast–southwest, is bounded on the southeastern edge by the Springs fault, and the pools may be connected along the western side of the fault. C. A. F.

2462. Stratigraphy and structure of mountains northeast of Santa Barbara, California. B. M. Page, J. G. Marks, and G. W. Walker. *Bull. Amer. Ass. Petrol. Geol.*, 1951, **35** (8), 1727–80.—The area described is in Santa Barbara County, California, 80 to 90 miles northwest of Los Angeles. It comprises parts of the Santa Barbara, Carpinteria, Little Pine Mountain, and Hildreth Peak quadrangles of the U.S. Army Corps of Engineers. From Santa Barbara, the nearest large town, this mountainous and brush-covered region is partly accessible by roads, most of which are controlled by the U.S. Forest Service.

The stratigraphic section is remarkable for its great thickness (more than 28,000 ft) of Cretaceous and Eocene sandstone and shale. These sediments, which are marine but only scantily fossiliferous, greatly predominate over the other rocks in areal extent. In this paper the Cretaceous strata are divided into three formations: the undifferentiated Cretaceous shale, the Debris Dam sandstone, and the Pendola shale, the two latter formations being newly named.

Lower Eocene rocks are lacking. There is an important angular unconformity at the base of the middle Eocene section. The well-known Sierra Blanca limestone of middle Eocene age locally comprises the basal unit of the Eocene rocks. It is overlain by the thick Juncal formation (middle Eocene shale and sandstone) which is here defined for the first time. Above this are the Matilija sandstone, Cozy Dell shale, and "Coldwater sandstone"—all Upper Eocene in age, and all previously described by others.

The Oligocene is represented by the non-marine Sespe formation, and the Miocene rocks include "Temblor" sandstone and Monterey shale. At the base of Miocene section there is a striking angular unconformity.

The Santa Ynez fault, which extends east and west across the area (and beyond), is the most important structural feature. It is a steeply dipping fault of Quaternary

age, probably with both a reverse and a strike-slip component of displacement. North of this fault the rocks are folded along northwest–southeast axes in accordance with the general pattern of California Coast Range structure. South of the fault, however, the formation in general strikes east–west in harmony with the Transverse Ranges, of which the Santa Ynez Mountains are a member.

The oldest rocks belong to the Franciscan group (Jurassic ?) and consist chiefly of structurally disorganized dark shale with isolated bodies of sandstone, contorted chert, and other types of rock. E. N. T.

2463. Exploration and drilling activity at all-time high in San Juan Basin. P. C. Ingalls. *Oil Gas J.*, 2.8.51, **50** (13), 62.—There is active development of gas fields in the San Juan Basin in northwestern New Mexico and southwestern Colorado, and as a result of discoveries and extensions during the last four years, gas reserves are now estimated at over 10 million cu. ft., as compared with 15 trillion cu. ft. in Kansas, 103 trillion cu. ft. in Texas, and 26 trillion cu. ft. in Louisiana.

Main gas pays in the basin are the Upper Cretaceous Pictured Cliffs and Point Lookout sands and the Pennsylvanian Lower Paradox limestone. Paradox production at Barker Creek was discovered in 1945. The field is an asymmetrical anticline defined at the surface by the Upper Cretaceous Mesaverde. 450 to 500 ft of closure are present at the Paradox Second Zone level. The discovery well flowed 25 million cu. ft. gas/day on open flow.

The Upper Cretaceous pays are generally tight, with Pictured Cliffs potentials varying from 50,000 to 400,000 cu. ft/day and Point Lookout, from 100,000 to 10,000,000 cu. ft/day. The gas accumulation in these sands is believed to be "blanket-type" saturations trapped in sand belts which wedge-out northeastwards. Water is found structurally higher than the gas on the southwestern edge of the basin, and this may be encroaching downdip, gas being dissipated at the outcrop.

A table lists the oil and gas fields of the basin, and a stratigraphical cross-section, location maps, and facies diagram are included. C. A. F.

2464. Wildcat tests 2,341 bbl. Anon. *Oil Gas J.*, 26.7.51, **50** (12), 179.—1 Breedlove Martin County, Texas, was completed for 2341 b.d. of 41·3° oil from the Devonian at 12,078 to 12,118 ft. The well is in the Midland Basin. C. A. F.

2465. Buried hill at Wilcox–Carrizo Contact in East Texas. H. B. Stenzel. *Bull. Amer. Ass. Petrol. Geol.*, 1951, **35** (8), 1815–28.—In East Texas, a recently discovered buried hill, at least 77 ft high, is composed of strata of the Wilcox group (lower Eocene) and covered on its flanks by cross-bedded sands of the lower Carrizo and at the top by level-bedded shales and silts of the upper Carrizo formation. Peculiar small funnel-shaped pits filled with Carrizo sand extend into the underlying Wilcox ball clay at the peak of the hill. Other extensions fill shrinkage cracks of the clay. These and other features of the contact demonstrate a disconformity at the base of the Carrizo sand caused by rejuvenation that occurred shortly before Carrizo sand deposition.

The buried hill topography discussed here has important practical consequences in the search for additional deposits of the valuable clay and in the use of the Wilcox–Carrizo contact as a horizon on which to map structures favourable for the accumulation of petroleum. It also emphasizes the division between the Wilcox and the Carrizo, and favours placing the Carrizo formation in the Claiborne group rather than in the Wilcox group. E. N. T.

2466. Triassic and Jurassic stratigraphy on southwestern Montana. C. A. Moritz. *Bull. Amer. Ass. Petrol. Geol.*, 1951, **35** (8), 1781–814.—In southwestern Montana the Triassic system is represented by marine sandstone, siltstones, limestones, and shales and by non-marine redbeds, all of early Triassic age. These beds are correlated with Dinwoody, Woodside, and Thaynes formations of southeastern Idaho, western Wyoming, and northeastern Utah. The system is widely distributed, and ranges in thickness from zero in Silver Bow County to more than 1500 ft in southern Beaverhead County. These sediments were deposited under relatively stable to mildly unstable conditions along the margins of the geosyncline, the axis of which lay west of this region during the Triassic, as well as during the Paleozoic.

The Jurassic system is represented by marine sediments that are correlated with

the Sawtooth, Rierdon, and Swift formations of the Middle and Upper Jurassic Ellis group and by non-marine deposits that represent the Upper Jurassic Morrison formation. Jurassic strata are thin or missing in the northern and central parts of the region, as the result of the development of a small but prominent positive area, and they thicken eastward in Gallatin County and southward and westward in Beaverhead County. The marine Jurassic rocks were deposited under shelf conditions, and the axis of the geosyncline still lay west of this region during the Jurassic. The presence of subgraywackes in the Morrison formation presaged the eastward shift of the geosyncline axis into this region, which occurred in the Cretaceous. E. N. T.

2467. Rubble bedding and graded bedding in Talara formation of northwestern Peru. J. M. Dorreen. *Bull. Amer. Ass. Petrol. Geol.*, 1951, **35** (8), 1829–49.—Rubble bedding is a feature resulting from subaqueous mudflows following subaqueous tectonic movements. The bedding is characterized by a complete absence of sorting and by the presence of erratics of inclusions. Rubble bedding is essentially the redistribution of semi-, or completely, consolidated sediments.

Graded beds, consisting of alternating sands and shales, can be expected as a normal sequel to rubble-bedded deposits, since conditions on the slope are such as to permit the accumulation of unstable masses of soft sediments. Sloughing occurs from this.

Both phenomena as found in northwestern Peru are classed as secondary deposits, as contrasted to primary deposits which have undergone subaerial and subaqueous transportation and precipitation into a primary depositional environment.

E. N. T.

2468. Cumarebo oil field, Falcon, Venezuela. A. L. Payne. *Bull. Amer. Ass. Petrol. Geol.*, 1951, **35** (8), 1850–78.—The Cumarebo oilfield, situated near the coast in northeast Falcon, is operated, and now entirely owned, by the Creole Petroleum Corporation. It was discovered in 1931, and development was largely completed by 1940, but intermittent drilling was continued until 1947. The total number of wells in and around the field is 133. The proved area, 550 acres, is about 2 miles long, with an average width of $\frac{1}{4}$ mile. The gravity of the oil produced ranges from 47·0° to 50·5° API.

The strata cropping out in the field belong to the middle Miocene Caujarao formation. Production is obtained from the ten oldest sands of this formation and from the two sands in the uppermost 850 ft of the Lower Miocene–Upper Oligocene Mosquito formation (a new name : other new formation and member names are also published in this paper). These sands, ranging in net sand thickness from 16 to 178 ft, have not been found productive elsewhere in the area. Production from older beds has also been sought, unsuccessfully, both on the Cumarebo structure and elsewhere in the area.

Because of the step faulting and multiple sands, producing depths in the field vary widely, ranging between 600 and 2893 ft. All the reservoirs now produce by gas-cap drive, and there is also a water drive on one flank of the biggest reservoir. Pressure maintenance by gas injection was started in 1933; the project was tried in all the more important reservoirs, but is now confined to the two largest with highly beneficial results. The maximum rate of oil production was attained in 1933, with a daily average of 13,511 brl. At the end of 1950 the potential of the field was 4000 brl of oil per day. The cumulative production at December 31, 1950, was 42,365,200 brl of oil. E. N. T.

2469. Gas found in Emsland. Anon. *Oil Gas J.*, 2.8.51, **50** (13), 52.—Frenswegen 1, north of Nordhorn near the Dutch–German border in Emsland, found gas at 6316 ft in the Zechstein Plate dolomite, which produced gas in the Bentheim field. C. A. F.

2470. New Guinea programme. D. M. Duff. *Oil Gas J.*, 22.5.51, **49** (42), 139.—Exploration in New Guinea, which was resumed after the war, has been considerably expanded. Surveys have been carried out in southeastern Papua. High rainfall and swamp conditions have complicated the work, and there have been drilling difficulties due to heaving shale. Wells are being drilled at Wana (9866 ft), Omali, and a site at Hohoro near the coast is to be drilled where there are nearby gas seeps. Dry wells have been completed at Kariava, near the Vailala River; Oroi, 56 miles northwest of Port Moresby; north of Hohoro; and at Hohoro. C. A. F.

Drilling

2471. Variations of hydrostatic pressure during extraction of the drillpipe from the hole. M. Gawlinski. *Nafta*, July 1950, **6**, 188–92.—A summary of experiments is presented showing how the chances of a blow-out are affected by drilling muds of varying gravity, visc, and structural resistance. The manner in which the drillpipe is withdrawn plays an important part. Results are represented graphically. M. S.

2472. Carrying capacity of drilling muds. C. E. Williams and G. H. Bruce. *Petrol. Tech.*, Apr. 1951, **3** (4), *A.I.M.M.E. Tech. Paper No.* 3026, 111–20.—Laboratory and field tests have been carried out to examine the factors which affect the carriage of cuttings by drilling mud. It was found that turbulent flow in the annulus is desirable for cutting removal. Low visc and low gel strength also favour the rapid removal of cuttings, and high density also increases the carrying capacity of the mud. The carrying capacity of the mud was greater when the drillpipe was rotated than when it was stationary. It was concluded that if turbulent flow can be maintained an annular velocity slightly higher than the slip velocity of the largest particles to be removed should keep the hole clean. For this purpose mean velocities of 100 to 125 ft/min seem adequate, although current practice uses 175 to 225 ft/min.

Details are presented for the experimental particles, and the muds used, together with the slip velocities. The mechanism of particle carriage is described, the theoretical expectations having been confirmed by visual means in the laboratory.

G. D. H.

Production

2473. The Shuler Jones sand pool; nine years of unitized pressure-maintenance operations. J. Tarner, W. R. Evans, and H. H. Kaveler. *Petrol. Tech.*, Apr. 1951, **3** (4), *A.I.M.M.E. Tech. Paper No.* 3054, 121–6.—The Shuler Jones sand pool, Arkansas, was discovered in September 1937, unitized in February 1941, subjected to gas injection in July 1941, and to water injection in July 1944. Early material balance calculations assumed no water advance, and gave values for oil in place of 100 to 109 million brl. After unitization the calculations have had gradually increasing values which indicated water advance.

The early prediction was that the producing G.O.R. under gas injection would be about 20,000 cu. ft/brl when the recovery was 54,000,000 brl, and when on the basis of 90% return of the gas the reservoir pressure was about 600 p.s.i. At present the recovery is 50,000,000 brl (about half the oil in place), and the average G.O.R. is less than 4500 cu. ft/brl, with a reservoir pressure of 1400 p.s.i. A reasonable expectation for primary recovery without unitization would have been 34,000,000 brl. The annual rate is about 2,500,000 brl, and about 60% is currently flowing.

There are 149 wells which could be used for production. Only forty to sixty have been operated at any time, and 126 have been used at some time or other in the past nine years for production or injection purposes. G. D. H.

2474. A study of reservoir performance of the First Grubb pool, San Miguelito field, Ventura County, California. Anon. *Petrol. Tech.*, Sept. 1950, **2** (9), *A.I.M.M.E. Tech. Paper No.* 2951, 243–60.—The San Miguelito field is an asymmetrical anticline, 2 miles long and ¾ mile wide with a northwest–southeast trend. The west flank dips at 40°, and the east flank at 60–75°. The First Grubb pool comprises eight Lower Pico and Repetto siltstones and sandstones separated by shales. Forty-eight producers have been completed since the discovery of the pool in 1931. There is 685 ft of pay in 1220 ft of sandy section. The cumulative production is 15,600,000 brl from 276 acres. The weighted average porosity of 800 samples from twenty wells is 18%, while the average permeability is 86 mD. The extent of the productive sands increases with depth.

The original saturation pressure is estimated as 3000 p.s.i.g. at −5500 ft and 158° F. A formation volume factor of 1·428 was used. Reservoir oil visc was 0·92 cp, and the solution G.O.R. 890. Gravity drainage has been effective in maintaining a high oil saturation down flank, but the reservoir is primarily of the solution-gas-drive type. Gas injection was initiated in 1940.

In spite of heterogeneity of the sands, lamination, and faulting, there is evidence of interference between wells. A number of early water-base mud wells had abnormally low productivity indices after an initial clean-up period, and in one case the index had improved by about 60% when the cumulative production was 126,000 brl. G. D. H.

2475. A petroleum engineering progress report on the Scurry field. W. L. Horner. *Petrol. Tech.*, Apr. 1951, **3** (4), 17–18.—The producing area of the Scurry group of fields is 40 miles long and up to 8 miles wide. Production is from a buried Pennsylvanian limestone reef with up to 750 ft of oil saturation at depths of about 6500 to 7000 ft. The Sharon Ridge, Diamond "M," Kelly-Snyder, and Cogdell areas cover 85,000 acres. In Nov. 1950, 1537 wells gave 4,481,413 brl and at the beginning of Dec. 1950 the cumulative production was 38,600,000 brl. In Jan. 1951 the allowable was 2200 brl/well/month.

The stock-tank oil in place is estimated as 3,500,000,000 to 4,000,000,000 brl. Porosity of the entire reef section averages between 5 and 8%. The water levels are believed to differ in the different areas. About half of the reservoir rock consists of recognizable fossil fragments, mainly foraminifera and echinoderms, and most samples show recrystallization. Half the samples show fine fractures, mainly vertical. The reef is a bioherm, eroded to its present shape and covered with shale. A few wells have shown oil production in sand lenses in this shale. Underneath the reef some wells give oil from Strawn limestone, and there are also Ellenburger shows.

The field is on the east side of the Midland Basin.

The initial pressure at 4300 ft subsea was 3122 p.s.i.g. Bubble points ranged 1725 to 1946 p.s.i. Flash liberation gave a dissolved G.O.R. of 944 to 1168 cu. ft/brl. The corresponding formation volume factors are 1·57 to 1·69. Expansion from initial pressure to bubble-point pressure amounts to nearly 2%. In Jan. 1951 the typical reservoir pressure was about 2300 p.s.i. Water drive is absent.

Ellenburger water was being injected into the Canyon reef at 2000 b.d. Laboratory tests indicate that water will displace about 50% of the oil in place (8·8 to 76·2%). The permeabilities of the twelve test specimens ranged 0·5 to 203 mD, and 5·8 to 19% porosity. G. D. H.

2476. Variable characteristics of the oil in the Tensleep sandstone reservoir, Elk basin field, Wyoming, and Montana. R. H. Espach and J. Fry. *Bur. Mines Rept. Inv. No.* 4768, Apr. 1951.—Data are given of the results obtained in a study of the physical characteristics of bottom samples from nine wells in the Tensleep sandstone reservoir. The data indicate that the oil in the reservoir has unusually varying physical characteristics, such as a saturation pressure of 1250 p.s.i.a. and 490 cu. ft. of gas in solution in a barrel of oil at the crest of the structure, and a saturation pressure of 530 p.s.i.a. and 134 cu. ft. of gas in solution in a barrel of oil on the flanks. The hydrogen sulphide content of the gas in solution in the oil varies from 18% for oil at the crest to 5% for oil low on the flanks of the structure. Of even greater significance is the fact that these and other variable characteristics of the reservoir oil are related to the position of the oil in the structure. This is contrary to the opinion held by many experts that all the oil in a reservoir has uniform physical characteristics and the equilibrium conditions prevail in all underground accumulations of oil and gas. W. H. C.

2477. Use of centrifuge for determining connate water, residual oil, and capillary pressure curves of small core samples. R. L. Slobod, A. Chambers, and W. L. Prehn. *Petrol. Tech.*, Apr. 1951, *A.I.M.M.E. Tech. Paper No.* 3052, 127–34.—Although the use of the centrifuge for capillary pressure and allied studies was described in a number of papers some years ago, there have been no critical reviews of the possibilities of this technique. In the work described attempts have been made to examine the capacity of this method to supply useful, accurate data. The results are presented for a centrifuge giving 3800 r.p.m., and for a high-speed attachment which gives up to 18,000 r.p.m. Connate water was determined on small core plugs, and residual oil by air or water drive; capillary pressure curves were obtained. The system reaches equilibrium rapidly, 1 or 2 hr generally being sufficient. The results are more accurate and more reproducible than with the disk method because of attain-

ment of equilibrium, and the application of higher pressures, with the absence of errors due to poor capillary control.

The equipment is simple and compact. End effects can be eliminated by using butts. Comparison with observations made on the same cores by the capillary pressure method showed good correlation, especially for the more permeable cores.

G. D. H.

2478. Experimental investigation of factors affecting laboratory relative permeability measurements. T. M. Geffen, W. W. Owens, D. R. Parrish, and R. A. Morse. *Petrol. Tech.*, Apr. 1951, **3** (4), *A.I.M.M.E. Tech. Paper No.* 3053, 99–110.—Experiments on three-section plastic-covered plug assemblies properly constructed are considered to show that these assemblies behave as a continuous core in fluid flow. Pressure gradients can be selected which will confine the disturbing boundary effects to the end core section, thereby yielding true relative permeability characteristics for the middle section. In gas-oil flow tests on cores with partial water saturation representing connate water, the entire assembly must have the "irreducible minimum" water saturation, if water migration is to be prevented.

The relative permeability is not a single-valued function of saturation, because the saturation history involves effects which fix the statistical distribution of the fluids in the pores. Laboratory tests simulating reservoir conditions must have a similar saturation history. The relative permeability characteristics of a system in which the wettability does not change are not affected by the physical properties of the fluids involved. Thus gas–water and oil–water systems will behave identically provided that the saturation histories are the same. It appears possible that oil displacement by gas can be made more efficient than the natural process, since numerous relative permeability saturation relationships are possible in porous systems. A substantial amount of gas will remain in the pore space of a water-invaded gas or gas-condensate reservoir, and it is estimated that the range of trapped gas saturation will be 15 to 50%, and not the "critical gas saturation," which is usually taken as 1 to 11%.

G. D. H.

Oilfield Development

2479. 1950 foreign production review. E. W. Berlin, A. H. Chapman, and R. B. Gilmore. *Petrol. Tech.*, Apr. 1951, **3** (4), 11–16.—Twenty-six wildcats in Saskatchewan gave no significant oil discovery; four well were drilled in Manitoba. A 1127-mile pipeline from Edmonton to Superior was completed. Western Canada was second to Texas in geophysical activity, with an average of 110 parties (mainly seismic). There were ten new field finds. The Flint well, 45 miles southeast of Edmonton, found 35° API oil in the D-2 and D-3 zones. D-3 production was found at Stony Plains and Acheson north of Leduc-Woodbend. Twenty-three gas discoveries were made. 448 producers were completed at Redwater. In other Alberta fields 311 producers were drilled. Canada's oil output in 1950 was about 29,000,000 brl, about 95% being from Alberta.

Venezuela gave 544,000,000 brl of oil in 1950. The proven reserves are estimated at 9,000,000,000 brl. The Alturitas No. 1 well, drilled to 17,039 ft, 100 miles southwest of Maracaibo, found oil in Cretaceous limestone, but was completed in an Eocene sand at about 11,000 ft.

The Cerro Manantiales field of Chile is estimated to have reserves of 30,000,000 brl. Eleven oil and four gas wells have been completed. A wildcat at Cerro Sombrero several miles north of the proven area was recently completed for about 3000 b.d. Cerro Manantiales currently gives about 1500 b.d.

Colombia averaged about 92,000 b.d. Its reserves are placed at 40,000,000 brl. Twenty-nine oil wells, two gas wells, four dry holes, and a stratigraphic test were completed in Brazil. Oil output was 338,707 brl. Argentina produced about 63,500 b.d. The reserves are estimated at 300,000,000 brl. Ecuador gave 7200 b.d., with remaining reserves placed at 26,000,000 brl. Peru's reserves are estimated to be 170,000,000 brl. The 1950 output averaged 40,500 b.d. In Bolivia reserves are placed at 20,000,000 brl. The daily output was 2400 brl, mainly from Camiri.

A new pipeline in Iraq allowed the production to be increased from 85,000 b.d. to 165,000 b.d. The Burghan field of Kuwait is practically drilled up with ninety-nine

wells. The Ain Dar field of Arabia began producing late in 1950 at 100,000 to 110,000 b.d. Dukhan is giving 43,000 b.d. from twelve wells.

Seventy wells were completed in the Middle East in 1950, and the daily output averaged 1,742,649 brl.

Pakistan gave 3200 b.d., mainly from Dhulian, Khaur, and Balkassar. Digboi averaged 5100 b.d., while Burma averaged only 400 b.d. China may have given about 2000 b.d. from the Yumen and Kansu areas, and Japan 5500 b.d. There was considerable geological and geophysical activity. Sakhalin is believed to have given some 9000 b.d. British Borneo gave 79,600 b.d., principally from Siri. Indonesia gave 131,400 b.d. (Sumatra 95,000 b.d., Borneo 35,000 b.d.). The Klamono field of New Guinea gave 473 b.d.

Egypt produced 16,304,307 brl of oil in 1950. Six wells were drilled at Ras Matarma, two giving oil in the Miocene and one in the Eocene. The Feiran field has one producer in a tight Miocene sand at 6500 ft.

Holland averaged 13,372 b.d., and France 2625 b.d. from Lacq and Pechelbronn. Italy yielded about 200 b.d., and Morocco 810 b.d. England produced 700 to 800 b.d.

G. D. H.

2480. Oil and gas developments in the Atlantic coastal plain during 1949. E. W. Berry. *Petrol. Tech.*, Sept. 1950, **2** (9), 166.—A 300-ft well near Springfield, South Carolina, is supposed to be active, but no further drilling has been done on Fanny Collins No. 1, south of Conway. A rig between Winton and Harrellsville, North Carolina, has stood at about 1300 ft since May 1949. The oil is at or near basement. G. D. H.

2481. Rich field. Anon. *Oil Gas J.*, 9.8.51, **50** (14), 60.—Reserves of the Yenter field in the Julesburg–Denver basin, 10 miles northwest of Sterling, Colorado, are estimated at 11,000,000 brl in the J sand. Restricted production is 950 b.d. from nineteen wells. The discovery, 1 Koenig-Ashby, was completed in 1950 for 225 b.d. from the J.

C. A. F.

2482. Oil and gas developments in North Texas during 1949. W. G. Sinclair. *Petrol. Tech.*, Sept. 1950, **2** (9), 151–65.—2715 wells were drilled in 1949, 1521 being oil wells with a combined initial output of 209,864 b.d. There were fifteen gas wells. 128 new fields and extensions were opened. Seventy-one wells tested the Ellenburger, and seventeen found oil in this horizon, while nine were plugged back and completed in shallower beds.

2,685,800 brl of gasoline and 49,110,654 brl of crude oil were produced in 1949. The crude oil output was 1,937,213 brl below the 1948 figure. At the end of the year the cumulative output was 1,095,128,194 brl, and there were 21,021 producing wells, of which 1056 were flowing.

Tables give by fields the output, area, discovery date, number of wells, oil type, producing formation, etc. Important wildcats are listed with the main data, and there are summaries relating to various activities. G. D. H.

2483. Alaskan search to end. Anon. *Oil Gas J.*, 9.8.51, **50** (14), 58.—Exploration in the U.S. Naval Petroleum Reserve No. 4 in Alaska is to end this year. The oilfield discovered at Umiat is estimated to have recoverable reserves of 50 to 150,000,000 brl, and the Cape Simpson field, 200,000 brl. C. A. F.

2484. Colombia. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 185.—34,059,343 brl were produced in Colombia in 1950, compared with 29,722,366 brl in 1949. 105 wells were completed, of which six were wildcats.

Tables show oil productior, geological data, and drilling trends. C. A. F.

2485. Chile. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 180.—Production in Chile in 1950 was 630,950 brl, of which 586,680 brl were produced from Carro Manantiales and the remainder from the new Cerro Sombrero field.

Tables show wells completed in Chile in 1949 and 1950 and production and geological data. C. A. F.

2486. Ecuador. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 186.—2,690,983 brl were produced in Ecuador in 1950, compared with 2,615,051 brl in 1949. Seventy-seven wells were completed during the year, of which sixty-three were producers.

Tables show oil production, and engineering, geological, drilling, pipeline, and refinery data. C. A. F.

2487. Brazil. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 178.—Thirty wells were completed in Brazil in 1950, of which twenty-four produced oil and two gas. 1950 production was 338,675 brl.

Two fields were discovered in Bahia: the Almas field whose discovery produced approx 1000 b.d., and the Catu field in the northern part of the state. A wildcat near Belem at the mouth of the Amazon is drilling below 9000 ft.

Tables show oil production, drilling, geological, and refinery data. C. A. F.

2488. Great Britain. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 210.—340,067 brl of crude were produced in Great Britain in 1950, 1867 brl more than in 1949. Production of the Eakring field declined by 12,000 brl, but the Duke's Wood field increased production by 20,000 brl.

Two wildcats were drilled in Lancs and Notts in 1950; both were failures. Mansfield 1 was drilled to 4490 ft, and Formby 4 to 3880 ft, both in the Carboniferous.

Details of refinery expansion are included, and tables show oil production and geological and refinery data. C. A. F.

2489. France. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 200.—Seven wells are now producing in the Lacq field in the Aquitaine Basin, which was discovered in 1949. Total 1950 French production was 893,100 bfl, of which 447,000 brl were produced from Lacq. Pechelbronn production was 445,000 brl compared with 461,000 brl in 1949; twenty-eight producers were completed in 1950.

Wells have been drilled in Alsace and in the Languedoc Basin where thirteen wells were drilled; thirteen dry holes were also drilled in the Aquitaine Basin.

Tables give production, geological, drilling, refinery, and pipeline data. C. A. F.

2490. The Netherlands. Anon. *World Oil*, Int. Op. Issue, **133** (2), 15.7.51, 216.—Estimated production from The Netherlands in 1950 was 5,193,000 brl, 1,281,000 brl more than in 1949, a record.

Over 2700 acres are now proven in the Schoonebeek field, which supplies approx 30% of domestic requirements.

A new 20,000-b.d. refinery at Pernis commenced operations in 1950. C. A. F.

2491. Denmark. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 200.—Two tests completed in 1950, one near Frederikshavn City on the northeast coast and the other near Aalborg, were dry. Structure drilling and seismic work have been carried out. C. A. F.

2492. Germany. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 204.—7,830,000 brl were produced in Germany in 1950, 1,883,000 brl more than in 1949. 343 wells were completed during the year, of which 243 were producers. Sixty-two wildcats were drilled, of which two found commercial production. Areas under test were Emsland, Hamburg, Hanover, North Rhine–Westphalia, Suedwuerttemberg, Oldenburg, and Schleswig-Holstein.

Two pipelines have been completed; one from Ruehlermoor to Lingen (6 miles) and the other from Ruehlertwist to Osterwald (10½ miles).

Tables show German production for 1949, 1950, and geological, drilling, pipeline, and refinery data. C. A. F.

2493. West German reserves up. Anon. *Oil Gas J.*, 9.8.51, **50** (14), 68.—Reserves of Western Germany are estimated at 38,025,000 tons, or approx 270,000,000 brl, 1,500,000 tons higher than a year ago. C. A. F.

2494. Poland. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 222.—Estimated production in Poland in 1950 was 928,000 brl, compared with 965,000 brl in 1949.

No extensive new fields are believed to have been found. C. A. F.

2495. Roumania. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 222.—31,609,000 brl are estimated to have been produced in Roumania in 1950, 2,091,000 brl less than in 1949.

Reports indicate a new field in the northwest of Oradea–Mare near the Hungarian–Roumanian border in the Transylvanian region. C. A. F.

2496. Austria. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 198.—A well drilled in 1950 at Gaenserndorf near Vienna is reported to have initially produced 500 b.d.

Tables give production and geological and refinery data for the Austrian fields. C. A. F.

2497. Hungary. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 222.—Estimated production in Hungary in 1950 was 3,460,000 brl, 331,000 brl less than the record year in 1949.

Proven acreage in the Budafapuszta, Hahot, Hohot-Ederics, and Lovasi fields was estimated at 7950 acres. C. A. F.

2498. Czechoslovakia. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 222.—280,000 brl were produced in Czechoslovakia in 1950, 12,000 brl less than in 1949. A discovery was reported near Malacky, Slovakia, possibly an extension of the Austrian Zisterdorf fields. C. A. F.

2499. Yugoslavia. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 224.—489,000 brl were produced in Yugoslavia in 1950, 49,000 brl more than in 1949.

Production comes from Croatia, Bosnia, and Serbia, the Croatian fields producing approx 1270 b.d. There are three prospective fields in Serbia, bordering Russia and Bulgaria, and two wells are drilling near Tuzla in Bosnia. C. A. F.

2500. Italy. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 214.—71,779 brl crude were produced in Italy in 1950, 9532 brl more than in 1949. Cumulative production is 1,744,719 brl. 312 wells were producing, of which thirty-one were flowing at the end of the year. 1950 gas production was 18,302,889,924 cu. ft. The major gas field is Caviaga, where fifteen wells were producing at the end of the year.

Two wildcats were drilled in 1950, one of which, in Lombardia, found gas at 4625 ft. Exploration has been carried out in central and southern Italy.

Tables show production, and drilling, pipeline, and refinery data. C. A. F.

2501. Albania. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 222.—2,106,000 brl were produced in Albania in 1950, compared with 2,188,000 brl in 1949. C. A. F.

2502. Russia. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 218.—Estimated production in Russia in 1950, from available reports, was 263,165,000 brl, 30,165,000 brl more than in 1949.

The Aspheron peninsula area is reported to be producing approx 7 million brl/year.

Tables give engineering, geological, and refinery data on the U.S.S.R., Asiatic, and European fields. C. A. F.

2503. Algeria. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 224.—Algerian output in 1950 was approx 6984 brl. An important structure has been found in the hinterland of Oran, and more wells are to be drilled in the field at Oued Guetterin. C. A. F.

2504. Other Africa. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 228.—Exploration is continuing in the coastal plain of southern Mozambique between Lourenco

Marques and the Save River. Photo and airborne magnetometer surveys were completed in the area in 1949, and surface geological and geophysical work has been carried out. C. A. F.

2505. Tunisia. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 228.—Concession acreage in Tunisia is approx 18 million. Geological, gravimeter, seismic, and airborne magnetometer surveys have been carried out. C. A. F.

2506. Morocco. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 226.—Production in Morocco in 1950 was 291,220 brl, 147,050 brl more than in 1949. During the year a field was discovered at Sidi-Fili, and the limits of the Oued Mellah field were defined. Eighty wells were drilled during the year, of which forty-eight were in the areas of the Oued Bath, Oued Mellah, and Sidi-Fili fields.

291,220 brl were processed during the year at the refinery at Petitjean.

A table gives drilling data in Morocco. C. A. F.

2507. Egypt. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 224.—Egyptian production in 1950 was estimated at 16,275,000 brl, 278,000 brl more than in 1949. A new well in the Hurghada field averaged 250 b.d. on completion, and there are now forty-three wells pumping in this field averaging approx 23 b.d/well. A well has been completed in the northwest of the Sudr lease, and well 6 in the Ras Matarma area was completed in pay equivalent to that producing at Sudr and Asl. C. A. F.

2508. Ethiopia. Anon. *World Oil*, Int. Op. Issue, 15.7.51, **133** (2), 226.—Gumboro 1 in the Ogaden area was suspended below 10,000 ft in 1950. Geophysical work was continued during the year. C. A. F.

Transport and Storage

2509. Ohm's Law for gas flow in pipelines. Z. Wilk. *Nafta*, July 1950, **6**, 197–8.—Gas in long pipelines must be considered as a compressible fluid. The resistance of a long pipeline can be obtained using Jacob's formula of 1922 or others such as Weymouth's. All include λ = a coefficient of flow. Recent work shows the similarity between fall of pressure: $\Delta^2 = P_1^2 - P_2^2 = (c_1 s V^2)(c_2 L d^{-5})$ and Ohm's Law. (V = m^3/min, L = km, d = cm.) $(c_1 s V^2)$ is equivalent to the current intensity, and $(c_2 L d^{-5})$ contains the resistive property of the pipeline. Other relations for series and parallel connexions follow. M. S.

2510. Cut out trial and error. J. F. Heiss and H. C. Bramer. *Chem. Engng*, 1951, **58** (6), 112–14.—Nomographs are presented for solving complex series-parallel pipeline problems. The method of derivation and use is given, and five numerical examples evaluated. D. H.

2511. Friction losses in turbulent pipe-flow. L. E. Prosser, R. C. Worster, and S. T. Bonnington. *Fluid Handling*, July 1951, (18), 173–6. (*Inst. Mech. Engrs Hydraulics Group.*)—Developments in the establishment of a rational basis for the empirical logarithmic laws for pipe friction are reviewed. Commercial steel and wrought-iron pipes lie between the Prandtl smooth-pipe law and the Nikuradse laws for rough pipes. The apparently empirical relation $V = Am^x i^y$ is shown to be related through f, the friction coefficient, to Re and k/d, where A, x, y are constants depending on pipe character and fluid viscosity; m is hydraulic radius; i is hydraulic gradient; k/d is the ratio of roughness size to pipe dia. For wrought-iron and steel pipes with $d < 50$ inches and $v < 20$ ft/sec values are given of $A = 154$, $x = 0{\cdot}76$, $y = 0{\cdot}535$.

It is concluded that the errors of pipe friction calculated in a practical case from the simple equation are not as high as other effects such as accuracy and uniformity of diameter, joints and fittings, and variations in roughness. D. H.

2512. Gasoline storage in contact with water and various container walls. J. Boué, J. Ferrier, and M. Louis. *Rev. Inst. franç. Pétrole*, 1951, **6**, 305–11.—Complex nature of aviation gasolines makes them particularly liable to deterioration on storage. Tests

were carried out on laboratory, pilot plant, and full scale with 100/130 grade U.S. gasoline complying with French spec ANF 48 b (30/12/48). Gasoline was stored in contact with seawater, fresh water, concrete, and various plastics used for coating concrete. Duration of pilot-plant tests was ten months (Sept.–June) in southern France at ambient temp. In laboratory and pilot-plant tests ratio wall area/vol was much greater than in practice. Full-scale trials were on gasoline stored over seawater in aircraft carrier. General conclusions are that aviation gasoline can, under average conditions, safely be stored for several years in either steel or concrete tanks in contact with fresh or seawater. If plastic coatings are employed on the concrete, care must be taken, since certain coatings, of the Thiokol type, can cause increase in S content, appearance of corrosive S, and fall in O.N. Under severe storage conditions over water, etc. (*i.e.*, involving considerable agitation), aviation gasoline will deteriorate fairly rapidly with loss of T.E.L., fall in O.N., and rise in gum. V. B.

2513. Normal (storage) losses of petroleum products. K. Kachlik. *Nafta*, July 1950, **6**, 198–202; Aug. 1950, **6**, 30–4.—A symposium of losses due to evaporation, new ideas on prevention of losses and their development. Fully illustrated by means of tables, graphs, and technical drawings. British, American, and German sources are quoted. M. S.

2514. New 8-day orifice-meter charts effect 20 per cent economy. Anon. *Oil Gas J.*, 6.9.51, **50** (18), 102.—A change from seven-day to eight-day orifice-meter charts for measurement of natural gas by Phillips Petroleum Co. has reduced number of charts per meter per month from five to four and effected 20% economies. Chart drives were changed, and the "inches differential" charts were also changed to "square root" division charts to provide one standard for the field system. G. A. C.

Refinery Operations

Refineries and Auxiliary Refinery Plant

2515. Good progress being made on Isle of Grain refinery. V. S. Swaminathan. *Refiner*, 1951, **30** (8), 109–10.—This Anglo-Iranian Oil Company's refinery will be processing 42,000 b.d. of crude oil in 1952. By the end of the same year, throughput capacity is to be doubled. A lube oil plant is scheduled to start operations in 1953, while in May of that year the cat cracker will come on stream. R. W. G.

2516. Supports for vertical pressure vessels. Pt II. F. E. Wolosewick. *Refiner*, 1951, **30** (8), 101–8.—The support of pressure vessels, allowing for stress due to changes in temp and pressure, is discussed at length. Article should be of assistance in designing such supports. R. W. G.

2517. Process variables in furnace operations. P. Buthod. *Oil Gas J.*, 30.8.51, **50** (17), 79.—A method is given for study of effect of changes in various process variables on the operation of an existing furnace, with particular reference to the radiant section. Problems studied include excess air, heat liberation, rate of heat absorption, bridge-wall temp, bridge-wall temp and excess air, and effect of operation changes on convection section.

Five actual problems are quoted and their solutions provided. G. A. C.

2518. Furnaces operation variables for process plant heaters. P. Buthod. *Refiner*, **30** (8), 77–82.—Several equations are presented enabling the effects of changing operating conditions of a pipe still to be predicted. Factors considered are radiant- and convection-heat absorption, heat generation, excess air and "bridge-wall" temp. By means of the equations presented, predictions may be made for wide change in operating conditions. Several useful illustrative examples are included. R. W. G.

2519. Multifuel burners, their application and design. W. H. Decker. *Mech. Engng*, 1951, **73** (8), 633.—Fuel-burning installations should be designed on the assumption

of the most economical continuous operation throughout the life of the installation. Unless adequate supplies of waste or by-product fuel are available, this will be assured only if the equipment is capable of handling solid, liquid, or gaseous fuels, the choice of fuel being dictated by current marketing considerations and handling and preparation costs. Availability-type combustion controls allow for fixed quantity of one fuel to be fired, while the second fuel is supplied to make up the balance of the load requirement as governed by the availability of the third fuel (usually waste or by-product). Numerous types of multi-fuel burners are described and illustrated.

T. T.

2520. Theory and practice of agitating and mixing. D. M. Newitt, G. C. Shipp, and C. R. Black. *Fluid Handling*, July 1951 (18), 189–92. (*Inst. Chem. Engrs, London*, July 1951.)—The fundamentals of mixing are defined and developed. Baffles fixed to the vessel walls are necessary for maintaining a uniform distribution, and do so because of the vortex street originating at the baffle surface. The power consumption in the turbulent region increases rapidly with size and numbers of baffles. A worked example of efficiency based on the rate of settling of suspensions gives 5% for a baffled tank.

D. H.

2521. Practical aspects of liquid mixing and agitation. B. N. Reavell. *Fluid Handling*, July 1951 (18), 170–2. (*Inst. Chem. Engrs, London*, July 1951.)—Laboratory-scale experiments are used to illustrate the effects of baffles in stirred tanks. The problems involved in scaling up data on small models are referred to, and normal industrial practice in design of impellers, mixing vessels, baffles, drives, and mountings.

D. H.

2522. Pumps for the chemical industry. E. F. Boon. *Ingenieur*, 10.8.51, **63** (32), Ch. 37.—A brief but wide survey is given on pumps which are used in industry. There are a large number of drawings and diagrammatic sketches covering practically every form of mechanism for transferring fluids from one place to another.

R. R.

2523. Further classification of refractories. R. A. Witschey. *Oil Gas J.*, 27.9.51, **50** (21), 115.—No. 90 of Refiner's Notebook series deals with refractory strength, and tabulates properties, including composition, fusion point, coeff of expansion, thermal conductivity and deformation under load.

G. A. C.

2524. Refractory material. Anon. *Oil Gas J.*, 13.9.51, **50** (19), 139.—No. 88 in the Refiner's Notebook series lists properties of refractory materials, including m.p., hardness, specific heat, thermal expansion and conductivity, and electrical resistivity.

G. A. C.

2525. Cooling towers and air-cooled exchangers. H. E. Degler. *Oil Gas J.*, 6.9.51, **50** (18), 76.—Selection, operation, and maintenance of cooling equipment is described, following a discussion on principles of evaporative cooling. Cost evaluation is dealt with, and an example worked out. Methods for prevention of icing during cold weather are included.

G. A. C.

2526. Cooling water treatment. D. Miller. *Oil Gas J.*, 23.8.51, **50** (16), 139.—Current practice and actual experience in cooling-water treatment at a number of plants is reviewed, and study made of correlation between theory and practice. Types of systems, general design considerations, prevention of excessive scaling and corrosion, deterioration of cooling-tower wood, treatment modification for closed or once-through systems, and miscellaneous chemical treatments are dealt with.

G. A. C.

2527. Pollution control. Anon. *Chem. Engng*, 1951, **58** (5), 111–58.—The causes of pollution in water, sampling and metering, separation, treatment, and disposal of effluent from a wide range of industries are covered.

Apparatus for the separation of air pollutants is reviewed.

D. H.

Distillation

2528. Selection and operation of distillation plant (2). G. A. Dummett. *Chem. Prod.*, Aug. 1951, **14** (8), 287–91.—This article continues the consideration of factors important in the selection and operation of distillation plant by discussing vapour velocity, fractionating efficiency, reflux flow, stability and flexibility, pressure drop, fouling, and cost. (*Cf.* Abs. 2113.) Consideration is then given to the principal features and advantages of the four main types of fractionating columns in current use, namely, packed columns, perforated plate, bubble-cap plate, and West plate columns. M. C. B.

2529. A constant reflux ratio distilling head. L. Berg and L. K. Smith. *Industr. Engng Chem.*, 1951, **43** (1), 233.—A constant reflux-ratio distilling head suitable for use with laboratory columns is described. A vertical jacketed cylinder with an internal-finger-type condenser is used, the condensate being withdrawn by a cup at the base of the finger. Rate of draw-off is controlled by a tap. F. M.

2530. Pressure drop through bubble caps. Pt II. Equipment and evaluation of equations. J. L. Huitt and R. L. Huntington. *Refiner*, 1951, **30** (8), 111–18.—(See Abs. No. 2117.) This second article of the series of three describes the equipment used for investigations, and discusses the evaluation of the theoretical equations. Many data are presented, comparing calculated and experimental values. R. W. G.

2531. Importance of the azeotropic distillation for coal tar processing. H.-G. Franck. *Brennstoff-Chemie*, 1951, **32** (13–14), 199–203. (*Coal tar session of Rhenish-Westphalian technical high school, Aachen*, 17.4.51.)—From its essentially aromatic nature coal tar has little tendency to form azeotropic mixtures. Thus the azeotropic dist process is of little quant val, but it is applied successfully to pre-purified fractions obtained by normal dist which consist of a small No. of separate materials. For preparing pure compounds the phenols and bases are washed out from the fractions concerned. Theories of the azeotropic dist process and the properties essential to the carrier are discussed. The application of the process and the carriers used in preparing pure materials from fractions with a narrow boiling range are illustrated by the following examples: the preparation of indole and diphenyl from indole oil using diethylene glycol; cumarone from the cumarone fraction of the light oil, using 1 : 2-propylene glycol; naphthalene and thionaphthene, using ethylene glycol; ethyl benzene and *p*-xylene from the fraction remaining after resinification of the light oil with formaldehyde and sulphuric acid, using ethylene glycol; 2 : 6-lutidine, β-picolin, and γ-picolin, using organic acids or water. Relevant data are tabulated. R. T.

2532. Effect of pressure in azeotropy. H. Skolnik. *Industr. Engng Chem.*, 1951, **43** (1), 172–6.—A method is described for the prediction of the pressure–temp relationships of azeotropes from data at a single pressure. Combined with the straight-line relationship between b.p. and composition this enables two accurately determined pressure–b.p.–composition data completely to define an azeotropic system. The method is illustrated by study of the following azeotropic systems: ethyl alcohol–ethyl acetate; ethyl alcohol–benzene–water; methanol–benzene; several hydrocarbon–water hetero azeotropes; and some maximum azeotropes. F. M.

2533. Vapour–liquid relations for system *n*-butane–*cis*-2-butene–furfural–water. F. Wally, J. A. Gerster, and A. P. Colburn. *Industr. Engng Chem.*, 1951, **43** (1), 162–72.—Experimental data are given for binary, ternary, and quaternary systems of *n*-butane, *cis*-2-butene, furfural, water. The previously developed use of three suffix Margules equations for prediction and correlation of vapour-liquid data has been expanded, and recommendations are made for estimating vapour–liquid equilibria for similar systems from a limited amount of basic data. F. M.

2534. Patent. Ger. P. 812,246, 28.6.51. O. Hubmann, E. Siebert, H. Maier, and R. Jauernik. Metallgesellschaft A.-G. Distributor tray for washing towers and columns. *Brennstoff-Chemie*, 15.8.51, **32** (15–16). R. T.

Absorption and Adsorption

2535. Critical conditions of two-phase flow in packed columns. B. J. Lerner and C. S. Grove, Jr. *Industr. Engng Chem.*, 1951, **43** (1), 216–25.—Experimental data are present for air–water counter-current flow through a 6-inch-dia, 7½-ft high packed tower. 1-inch clay Raschig rings, 1-inch Berl saddles, and ½-inch clay Raschig rings were used as packing material supported on a perforated plate. The data are used to illustrate the authors' theory on the mechanism of loading and flooding in packed columns. An expression is derived for the linear pore velocity of the gas in wetted packing, Vg, in terms of the superficial liquid and gas rates. The load point is postulated as occurring when the critical value of Vg is reached at the minimum free cross-sectional area of the packing. Equations are developed for calculation of loading and flooding velocities. F. M.

2536. Velocities and effective thermal conductivities in packed beds. M. Morales, C. W. Spinn, and J. M. Smith. *Industr. Engng Chem.*, 1951, **4** (1), 225–32.—Fluid velocities in packed beds have been investigated using a bed 2-inch I.D. packed with ½-, ¼-, and ⅛-inch cylindrical pellets through which air was passed. Flow measurement was by calibrated hot-wire anemometers. The results show that for bed depths above 2 inches the velocity decreased both near the tube wall and near the tube centre, giving a maximum value at a point between the centre of the tube and the wall. Similar variations with radical position were observed in the effective thermal conductivity group (Ke/C_pG, where K_e = effective thermal conductivity, B.Th.U/(hr.ft.° F.) C_p = specific heat of air at constant pressure, B.Th.U/lb.° F. G = air mass velocity, lb/(hr.sq.ft.) at any point in the tube).

The authors suggest that the variations in Ke/C_pG are the result of the non-uniform velocity profiles. F. M.

2537. Technical production of low-boiling hydrocarbons. K. Bratzler. *Erdöl u. Kohle*, 1951, **4**, 478–86.—Processes for large-scale hydrocarbon production over past thirty years are chronologically briefly reviewed (decomposition of coke-oven gas, natural-gas processes, high-pressure hydrogenation, Fischer–Tropsch syntheses, and various pet cracking processes). Application of low-temp, absorption and adsorption techniques to production of low-boiling hydrocarbons, and the economic, physical, and chemical factors governing their choice are discussed. Low-temp can be attained either by compression followed by expansion cooling or by indirect refrigeration. Latter process is cheaper than former, since it offers up to 95% energy recovery compared with 50 to 55%. Details and flow-sheets are given of processes for conversion of high-pressure hydrogenation waste gases to butane, propane, ethane, and production of ethylene from coke-oven gas. Absorption process (chiefly used for benzole recovery) is more adaptable to changes in gas composition. Modern absorption process for separation of propane, butane, and other light hydrocarbons from natural or cracked gases is fully described. Adsorption processes, based on special properties of adsorbents such as activated charcoal, effect considerable power-saving. Descriptions and flow-sheets are given of batch production of gas oil and gasoline from Fischer–Tropsch waste gases and of continuous Hypersorption and Rectisorption processes. Disadvantages and operational difficulties of the various methods are discussed. P. V.

Solvent Extraction and Dewaxing

2538. State of our knowledge of the extraction and composition of concentrated aromatic extracts from mineral oils by means of selective solvents. E. Terres. *Brennstoff-Chemie*, 1951, **32** (9–10), 134–47.—Experience gained through two decades in the Edeleanu laboratories in Germany and America in the construction and operation of plants for the extraction of gasoline cuts using liquid sulphur dioxide, with or without the aid of auxiliary solvents, is reviewed. Importance is attached to the production and use of gasoline extracts rich in aromatics for the synthesis of anti-knock mixed gasoline from straight run distillation. The isotherm of the counterflow extraction of a heavy gasoline cut in three steps at −60° C is represented in triangular co-ordinates and the practical representation of a flow scheme of an Edeleanu plant for this pro-

cedure is shown. The influence of the extraction temp on the concn of extract in aromatics and the mixed gasoline produced is represented graphically. The relation between aromatic cont of an extract and its density, also its O.N., is shown in charts. Behaviour in the motor of the conc extract and the mixed petrol produced therewith are discussed. An example of the operation of propane as an auxiliary solvent is the preparation of pure toluene from a hydrogenation petrol rich in aromatics. The fine fractionation of two gasoline extracts of max concn indicates the individual components and the relative quantities present. Extensive tabulations and graphs are given. R. T.

2539. Production of extraction gasolines (petroleum ether) of low aromatic contents. F. Sikora and A. Wachal. *Nafta*, May 1950, **6**, 128–32; June 1950, **6**, 162–5.—Great toxicity of C_6H_6 and $C_6H_5CH_3$ present to the extent of over 10% in pet ether obtained from Polish crudes presents a problem to industry using this solvent. Aromatic hydrocarbons are toxic in proportion of 1 mg/litre, and deadly dose is 6 cc/1 kg wt of man. By producing gasolines for extraction purposes such that would contain less than 5% aromatics, all dangers could be avoided. Since Edeleanu process is not in use in Poland, the authors suggest use of 96% ethanol (aq) in proportion of 15% for use in azeotropic distillation. This gave 38% yield, whereas ordinary distillation would give 22% yield by collecting fractions boiling from 78° to 102° C and 108° to 128° C. All results are tabulated, and details of experiments are given also for azeotropic distillation using cresols and ketones, in particular acetone, which gives 23% yield of petroleum ether of 2·5% aromatic content, which by the use of H_2SO_4 can be reduced to 1%. Removal of acetone is effected by aqueous ethanol. M. S.

Cracking

2540. New 420 ton/day delayed coking unit. O. A. Fuchs. *Petrol. Process.*, 1950, **5** (10), 1058–62.—A coking unit has been recently completed at the El Dorado, Ark., refinery of Pan. Am., Southern Corp. Designed and constructed by Lummus Co., it is reported to be the largest of its type, the two coke drums of which are 17 ft 6 inches dia and 96 ft 5 inches flange-to-flange length. The charge rate is 9300 b.s.d. of 13° API reduced crude with a designed daily production of 1950 brl depropanized 400° E.P. gasoline, 5240 brl gas oil for cat cracking, and 420 tons of coke. The hydraulic decoking equipment utilizes an eight-stage centrifugal pump delivering at 1825 p.s.i. at the top of the drums. Coke falls from the drums down a ramp to a dewatering basin, from where it is removed to storage by a dragline scraper. D. W. F.

2541. Exothermic reaction technique. M. Sittig. *Petrol. Process.*, 1950, **5** (10), 1080–2.—Exothermic reaction techniques are classified and their application for heat-removal and temp-control purposes in industrial chemical processes reviewed. Molten-salt baths may be used as combined catalytic and heat-transfer agents, as when directly contacted by the process gas, or purely as a heat-transfer agent, as in the regeneration step of some catalytic cracking processes. Fluidized solids reactors are playing a much greater part in heat control, especially in fluid cat cracking and in the improved Fischer–Tropsch process, whereby the required cooling surface area is greatly reduced. The application of rocket-motor techniques such as "sweat cooling" to chemical process reaction design is considered. Other techniques discussed include "film reactors," narrow channel reactors, the use of diluent gases, and fluid injection. D. W. F.

2542. Production of high octane gasoline components. Pt I. A. A. Draeger, G. T. Gwin, C. J. G. Leesemann, and M. R. Morrow. *Refiner*, 1950, **30** (8), 71–6.—Series discusses the chemical conversions affected in refining processes currently in use for the manufacture of components of motor and aviation gasolines, especially the behaviour of various hydrocarbon types rather than of individual compounds.

Pt I considers thermodynamically the production of high-octane components by cracking, polymerization, and alkylation. R. W. G.

2543. Solving catalytic cracking unit problems. J. Beam. *Oil Gas J.*, 6.9.51, **50** (18), 105.—A new booster for the check-valve in the turbo-blower discharge line, a flue-gas sample scrubber, and a simple efficient communications system made from war-surplus sound-powered telephones; installed at Cushing Refinery of Deep Rock Oil Corporation, Okla., are described. G. A. C.

2544. Production and purification of olefins and aromatics from petroleum as raw material. H. Steiner. *Schweiz. Arch. Ang. Wiss. Tech.*, 1951, **17**, 193–205 (in English).—A review of processes leading to olefin (principally C_2 and C_3) and aromatic production. High temp and low pressure favour olefin formation. Suitable charge stock is natural gas, C_2 and C_3 fractions being cracked at >600° C. Of processes developed for liquid stocks, the Catarole and T.P.C. also produce liquid by-products which are almost entirely aromatic. Former employs a cat, temp 650° to 700° C, with long contact times (30 to 60 sec) and latter operates at up to 850° C, using ¼- to ½-inch pebbles as heat-transfer medium. Typical compositions of gases and liquids from these processes are given with a detailed description of fractions isolated from the Catarole process. Four methods of separation and purification of olefins are described: (1) reversible chemical combinations of specific olefins with certain reagents, *e.g.*, copper salt solutions; (2) absorption of components in liquid solvents followed by stripping; (3) fractional sorption on and desorption from solid adsorbents; and (4) partial condensation followed by fractional dist. E. B.

2545. Patent. Ger. P. 814,148. Schweig, Sprengstoff-Fabrik A.-G. 26.7.51. Process for the production of a nickel reduction catalyst without supporter. *Brennstoff-Chemie*, 28.8.51, **32** (15–16), 28.8.51. R. T.

Hydrogenation

2546. Gaseous hydrocarbons in oil hydrogenation. M. Pier. *Brennstoff-Chemie*, 1951, **32** (9–10), 129–33.—Petrol is produced in Germany by dist of crude oil and subsequent catalytic pressure hydrogenation of the residue in the former coal-hydrogenation plant. This process, in contrast to other conventional cracking processes, yields a max of liquid products and practically no high-mol condensation products. Methane, ethane, propane, *n*- and *iso*butane are produced. Each of these gases contains more H_2 than the liquid product. Thus with increasing gas formation the H_2 consumption increases. This is suppressed by using suitable catalysts and hydrogenation conditions. The thermodynamic stability of the gaseous products decreases from methane to butane. The cracking hydrogenation, therefore, must not proceed to thermodynamic equilibrium. The gases produced, partly free and partly in solution, are obtained as C-poor gas used for H_2 production or as fuel and C-rich gas used as fuel or for production of chemical derivatives. The formation of gaseous hydrocarbons, especially of methane, increases with rising temp. Increase of pressure opposes the formation of small fragments. The use of suitable catalysts accelerates the formation of the desired liquid products, lowers the reaction temp, and the formation of gases, especially methane, is suppressed. Sump-phase hydrogenation and hydrogenation over a solid catalyst are discussed. The influence of raw materials, pressure and temp, and of specific catalysts on gas formation and the gasoline produced is considered. Comparisons are made between these hydrogenation processes for crude oil or petroleum residues, and for coal and coal tar with special reference to the final products. R. T.

Polymerization

2547. Benzene extraction and Platforming units. Anon. *Oil Gas J.*, 13.9.51, **50** (19), 120.—New units, to recover 17,600 g.p.d. of nitration-grade benzene in addition to up-grading saturated-type light and heavy naphthas, being installed at Shreveport plant of Atlas Processing Co., will be on stream early 1952.

Process consists of thermal reforming of low-octane fractions followed by catalytic gas polymerization.

Tables show yield *v* severity of up-grading and stock characteristics. G. A. C.

Chemical and Physical Refining

2548. New small-size sulfur-corrosion plant. G. Weber. *Oil Gas J.*, 23.8.51, **50** (16), 130.—A 10-ton sulphur-recovery plant to be operated by Lion Oil Co. in South Arkansas is described. Plant will recover elemental sulphur from sour residue gas produced locally, by the modified Claus process, whereby one-third of available supply of H_2S is burned to SO_2 and combustion product reacted with remaining two-thirds of H_2S over activated alumina catalyst to give elemental sulphur and water. Plant is entirely automatic. A flow sheet is given. G. A. C.

2549. Liquid–liquid extraction from single drops. F. B. West, P. A. Robinson, A. C. Morgenthaler, Jr., T. R. Beck, and D. K. McGregor. *Industr. Engng Chem.*, 1951, **43** (1), 234–8.—Data are presented on the extraction of acetic acid from benzene drops of known volume by water. Approx 14 to 20% extraction was obtained during drop formation. The subsequent extraction during the time of rise could be correlated empirically by equations for unsteady state diffusion in stagnant spheres. The results obtained differ considerably from those of previous workers, although no satisfactory explanation can as yet be given. F. M.

2550. Liquid–liquid equilibria in system benzene–pyridine–water. J. C. Smith, V. D. Stibolt, and R. W. Day. *Industr. Engng Chem.*, 1951, **43** (1), 190–4.—The " solutropic " system (cf. *I.P. Abstract No.* 2137, 1950) benzene–pyridine–water has been studied between 15° C and the normal boiling point. The variations in the limiting solubility curve and solutrope with temperature are unusual, and none of the published correlations describes the equilibrium relations. A list of solutropes is given, and it is shown that despite the solutropes, most of the systems can be used for extractions. The difference between " azeotropic " and " solutropic " systems is illustrated. F. M.

2551. Fractional liquid extraction. Relation between batchwise and continuous countercurrent extraction. E. G. Scheibel. *Industr. Engng Chem.*, 1951, **43** (1), 242–5.—An equation is presented for calculating the approach to steady-state conditions for each cycle of a batch-wise counter-current extraction operation,

$$\delta = \left[\frac{4E\left(1 - \frac{1}{N-1}\right)}{(E+1)^2}\right]^t$$

where δ = fractional deviation from steady-rate conditions;

n = feed stage location;

E = extraction factor $= \frac{LD}{M}$;

L = quantity of light solvent to each stage;

M = quantity of heavy solvent to each stage;

D = distribution coefficient. F. M.

2552. Fractional solvent extraction between immiscible solvents. Graphical calculation. E. L. Compere and A. Ryland. *Industr. Engng Chem.*, 1951, **43** (1), 239–41.—A cyclic counter-current batch-distillation procedure is presented which results in separation of solutes, paralleling that of a continuous counter-current process. By continuing the cycles it should be possible to separate any desired amount of material at constant purity of the products. A trial-and-error method of graphical calculation based on that of Varteressian and Fenske is given. This procedure permits the selection of operating conditions and the prediction of results for the separation of solutes which do not necessarily have constant distribution ratios. A comparison of predicted and observed experimental results in the five-stage separation of phenol and picric acid, using benzene and weak aqueous sodium chloride solution as the solvents, indicates the method to be valid. (Authors' Abstract.) F. M.

2553. Patents. Fr. P. 970,110, 29.12.50. Henstey et Cie. Process for the condensation and separation of volatile products contained in a gaseous mixture.

Fr. P. 973,716, 14.2.51. N. Marinesco. Desiccation of peat by electro-osmosis and thixotropy. *Brennstoff-Chemie*, 15.8.51. R. T.

Special Processes

2554. Continuous molding of paraffin wax is effected. L. H. Jennings, J. H. Beard, and V. A. Kalichevsky. *Refiner*, 1951, **30** (8), 97–100. (*Western Petroleum Refiners' Assoc mtng, Wichita, Kansas*, July 1951.)—A successful continuous wax-moulding unit, based on chocolate-moulding, is described. It is capable of 11,000 to 17,000 lb wax per hr—giving no slopped wax except on starting. The unit requires less floor space and five times as little labour as the conventional batch process. The wax cakes are exceptionally uniform in size (within 0·2% by wt of average) and have a bright lustre appealing to the eye. R. W. G.

2555. Patent. Fr. P. 977,009, 27.3.51. I. G. Farbenindustrie. Process for the dehydrogenation of alcohol. *Brennstoff-Chemie*, 15.8.51, **32** (15–16). R. T.

Metering and Control

2556. Differential pressure meters. A. Linford. *Fluid Handling*, July 1951 (18), 170–2).—The principles of Venturi, orifice plate, and Pitot tube meters are set out, and their suitabilities to different applications with gritty, viscous, or ordinary fluids are compared. Guidance is given on designing these standard meters. D. H.

2557. How to figure surge capacity when using level controllers. J. Conison. *Petrol. Process.*, 1950, **5** (10), 1072–5.—To avoid the consequences of rapid feed-rate fluctuations to a processing unit a level controller with a surge tank of adequate capacity to absorb the sudden change is required. Formulæ are developed for determining the surge capacity required, based on the max change of flow rate that may be expected, when used in conjunction with proportional and proportional plus reset-type level controllers. The two types are compared, and the necessary control value characteristics considered. D. W. F.

2558. Theory and use of automatic control. Anon. *Mech. World*, **130** (3370), 149. (*International Conference on Automatic Control, Bedford*, July 1951.)—The various types of process control that involve a closed sequence of dependence are mathematically equivalent. Summaries of numerous papers presented at the conference are given. The complete proceedings are to be published in volume form. T. T.

Products

Chemistry and Physics

2559. Inert gas effects in the oxidation of hexane. N. J. Small and A. R. Ubbelohde. *Nature*, 1951, **168**, 201.—Dilution of the system by H_2 leads to much more marked inhibition than the use of N_2 in the oxidation of gaseous acetaldehyde or of hexane. The mechanism of this inhibition can be represented by a deactivation of the peroxide radical thus:

$$R + O_2 \longrightarrow RO_2^*$$
$$RO_2^* + X \longrightarrow RO_2 + X^* \quad (X = H_2 \text{ or } N_2)$$

If H_2 is thus more efficient than N_2 in removing internal energy, it should also be more effective in cases where the supply of internal energy by collisions involves the reverse reaction, as in the thermal decomposition of ethane.

Traces of Hg vapour also produce an inhibiting effect on the oxidation of hexane. The same mechanism is proposed (X = Hg), although the reaction $R' + Hg \longrightarrow RHg'$ cannot be excluded.

The effect of H_2 in suppressing the formation of cool flames as in pentane appears to be a modification of the same reaction. H. C. E.

2560. A methane, proportional counting method for the assay of tritium. C. V. Robinson. *Rev. Sci. Instrum.*, 1951, **22**, 353–5.—This paper contains details of an apparatus and method for the preparation and assay of radioactive methane from radioactive water by reaction with methyl magnesium iodide. H. C. E

2561. Nature of the relationship between the calorific value of a fuel and its elementary composition. G. F. Knorre. *Izvest. Akad. Nauk S.S.S.R., Otdel. Tekh. Nauk*, 1951, 1202–8.—Effect of O_2 content on cal val is discussed and a linear relationship demonstrated between the cal val based on total oxidn products and the O_2 content. A constant for "heat-absorbing capacity of oxygen" is derived, this varies in range 3260 to 3620 cal/g for various hydrocarbon series, with 3330 as a typical value. The following expression is derived for the higher cal val of fuels :—

$$\text{C.V.} = (8880\,\text{C} + 26640\,\text{H}) \cdot \frac{1 - O_t/O_{th}}{1 - O_t} \cdot m \text{ cal/g}$$

when O_t is the total oxygen, O_{th} the oxygen required for combustion ; m is a correction factor ranging from 0·94 for anthracite to 1·04 for wood fuel and equal to 1·00 ± 0·03 for pet products. V. B.

2562. Thermochemistry for the petrochemical industry. Pt XVII. Some C_3 oxygenated hydrocarbons. K. A. Kobe, R. H. Harrison, and R. E. Pennington. *Refiner*, 1951, **30** (8), 119–22.—(See Abs. 1443 and 2186.) Data are presented for the free energies of formation, heats of formation, heats of combustion, and mol. wts. for carbon suboxide, acetone, *iso*propyl alcohol, *n*-propyl alcohol, and alkyl alcohol. Heat capacities, enthalpies, mean heat capacities, and heat-capacity equations are given for these compounds over the range 0° to 1200° C. R. W. G.

2563. Introduction to chemical reaction calculations. Pt 1. Introduction. A. M. Platt and G. L. Farrar. *Refiner*, 1951, **30** (8), 83–9.—Series is devoted to thermodynamics and chemical kinetics in order to classify the theoretical approach to chemical-reaction calculations for process engineers. Pt 1 discusses equilibria and presents a detailed and useful introduction to the use of fugacity and activity coefficients. Two numerical calculations of free energies are included. R. W. G.

2564. Temperature gradients and temperatures in carbon black flame. F. W. Jensen and K. Anderson. *Industr. Engng Chem.*, 1951, **43** (1), 176–81.—Temps and temp gradients within a bat-wing-type carbon-black flame have been studied using the Kurlbaum method for measuring true temperatures of luminous flames and noble-metal couples for determining temp gradients. Isothermal contour charts for horizontal planes from 0·25 up to 2·70 inches above the tip are given. The flame was found to be an ovoidal cylinder whose walls, composed of high-temp reacting gases, enclose a well-defined region in which carbon-forming reactions can take place. Temp of 1400° to 1450° C near the flame surface, dropping to 900° and 500° C in the interior zone of the flame, were recorded. F. M.

2565. Low temperature vapour–liquid equilibria in hydrogen–*n*-butane system. H. J. Arogan and D. L. Katz. *Industr. Engng Chem.*, 1951, **43** (1), 185–9.—Equilibrium vapour- and liquid-phase compositions for the hydrogen–*n*-butane system were determined at pressures from 300 to 8000 p.s.i. along a number of isotherms from 75° to −200° F, using a closed-flow-type system similar to that used by Dodge and Dunbar. Phase compositions, equilibrium constants, and bubble-point curves for the system are given, together with a graphical correlation for the prediction of equilibrium constants for hydrogen in binary hydrogen–hydrocarbon systems. F. M.

Analysis and Testing

2566. Modern techniques in petroleum testing. I. Distillation (Pt 1.) S. A. Ashmore and D. S. Vickery. *I.P. Review*, 1951, **5**, 210.—The importance of distillation in the oil industry can be judged from the fact that distillation equipment comprises about 25% of refinery capital investment. In the laboratory a straight distillation test can be performed to give an indication of the boiling range. Alternatively, a fractional distillation combined with examination of the fractions for refractive index or aniline point can be used to give more comprehensive information. The theoretical aspects of the process are described, including the phenomenon of azeotropy and methods for separating the individual components of azeotropic mixtures.

The operation of a fractionating unit is described, and the various terms connected with it are explained. Methods for determining the efficiency of fractionating columns are also described. This quantity is expressed as the H.E.T.P. (height equivalent to a theoretical plate) or as the H.T.U. (height equivalent of a transfer unit). Reference is made to special methods of fractional distillation, including vacuum distillation and extractive distillation. R. H.

2567. The progress of laboratory and road knock rating techniques. C. H. Sprake. *I.P. Review*, 1951, **5**, 187.—The methods used over the past thirty years to evaluate motor fuels may be divided into laboratory methods and those used in vehicles on the road. The former are intended to enable the practical behaviour of fuels to be predicted. Possibly the main factor in limiting the power of an engine is the tendency to detonate or "knock"—due to the too rapid burning of the fuel–air mixture. Great interest in "anti-knock" properties was first taken after the 1914–1918 war, when its importance upon engine efficiency was first realized. Various knock-testing engines were developed including that of Ricardo. In the early stages, audible detection of "knock" was relied upon, but in 1922, the bouncing-pin was invented by Midgeley to improve this technique. T.E.L. as an "anti-knock" additive was first adopted in the U.K. in 1927, and about the same time the Delco engine was developed. Various other developments in engines are described. The octane scale came into use in 1931, oils being assessed upon the basis of the percentage of *iso*-octane in an *iso*-octane/*n*-heptane mixture needed to give the same "knock" characteristics as the fuel in question. The assessment of temp sensitivity of motor fuels, the method of operating engines, and the correlation of engine results with practice are all described. R. H.

2568. Determination of benzene, toluene and xylenes in products and in workshop atmospheres by ultra-violet absorption in the vapour phase. J. Bouillot and A. Berton. *Chim. Anal.*, 1951, **33**, 261–6.—Method was developed with main object of determining toxic quantities ($> 0{\cdot}1$ g/m^3) of benzole in air; dilutions down to 0·01 benzene, 0·05 toluene, and 0·1 xylenes (g/m^3) can be simultaneously measured. Air sample (sample containers described and illustrated; tests show no separation of benzene or homologues from air sample, in fifteen days at concn up to 1 g/m^3) is transferred to a 18 mm $\times$ 5 m quartz-ended glass tube through which is passed beam from H-discharge lamp (1200 V, 150 mA). Photograph (40 sec exposure) is taken on Fery spectrograph and band intensities compared either visually or photometrically with those for air samples containing known concns of substances sought and photographed on same plate. At concn > 1 g/m^3 band widths in place of intensities can be used as quant criterion. Accuracy is $\pm 10\%$ and ten analyses/hr can be carried out. Method can be applied to products containing benzole by evaporating 25 mm^3 in a 10-litre vessel and testing air. Only interfering substance likely to be encountered is furfural, which masks benzole bands. Method can also be used with other volatile solvents, *e.g.*, CS_2, $C_4H_5NH_2$, and chlorinated hydrocarbons. Typical absorption spectra are reproduced. V. B.

Gas

2569. Utilization of natural gas in towns and settlements. Girzejowski. *Nafta*, June 1950, **6**, 158–62.—Natural gas can be used as chemical raw material, household fuel, precision fuel, or motor-car fuel. It consists practically wholly of methane and contains no sulphur compounds. Its cal. val. is high, and generally it occurs at fairly high pressures. Its use stands high on the list of the Polish six-year plan. Due to the difference in cal. val., flame velocity, and optimum air-to-gas ratio, simple introduction of natural gas into existing systems of gas mains and burners is impossible.

Account is given of the theory of calculation of corresponding pipe dia and gas pressures. Also of methods of reforming CH_4 with air or water to bring it to conditions similar to those of ordinary town gas. French and Czech experiments are quoted. M. S.

2570. LPG production now exceeds million barrels daily. R. C. Alden, F. E. Gilmore, and P. W. Tucker. *Oil Gas J.*, 23.8.51, **50** (16), 122.—A review of the LPG industry

in the U.S.A. is given. Reserves, basic rates of growth, sales, use in refineries, product available from refineries, and effects on refining are dealt with, and illustrated by tables and graphs.

It is concluded that inevitably new large markets must be found for the product.

G. A. C.

2571. Patents. Ger. P. 813,153, 12.7.51. (J. Schmidt) Carl Still. Device for producing a partial vacuum for generation by distillation.

Ger. P. 812,422, 5.7.51. E. Rössler. Schumacher'sche Fabrik, Bietigheim. Procedure and apparatus for the automatic separation of compressed gases or vapours from the liquids liberated from them.

Ger. P. 814,442, 26.7.51. H. Kölbel u. F. Engelhardt. Rheinpreussen. Procedure for the chlorination of gaseous hydrocarbons.

Ger. P. 813,870, 19.7.51. M. Goebel. Dr C. Otto & Co. Method of the production of carburetted water gas.

Ger. P. 810,656, 7.6.51. K. W. Gollum, Sachsenburg (Unstrut). High-pressure small acetylene generator.

Ger. P. 810,550, 7.6.51. O. Stebel u. H. Scholz. Hüttenwerk Hörde A.-G. Device for automatic sampling of gas from gas collecting tubes.

Ger. P. 810,323, 31.5.51. E. Karwat u. A. Hölzl. Ges. f. Linde's Eismaschinen. Process for the automatic analysis of technical oxygen.

Ger. P. 813,837, 19.7.51. K. P. Kalis. N.V. "Matera." Process for the production of methane.

Fr. P. 970,057, 6.8.48. Improvements to the closures of pits or vats, silos or reservoirs for the production of methane or analogous combustible gas. *Brennstoff-Chemie*, 15.8.51, **32** (15–16).

R. T.

Engine Fuels

2572 Liquid methane as fuel for the motor-cars. J. Kestin. *Nafta*, May 1950, **6**, 125–8; June 1950, **6**, 154–8 (reprint from *Przeglad Motoryzacyjny*, Nos. 21–22, Nov.–Dec. 1946).—Methane has a higher cal. val. and O.N. than petroleum. Its b.p. and crit temp present difficulties if it is to be used as motor fuel. These have been overcome by a group of research workers working at Imperial College, London. Details are given of their work and results.

M. S.

2578. Gas turbine tests on heavy fuel. Anon. *Gas Oil Pwr*, 1951, **46**, 163–5; 191–3.—After sea trials a Gatric gas turbine, designed for operation on gas oil, was used for bench tests on boiler-fuel blends and on fuel of high sulphur content without modification.

Tests were carried out on blends of boiler fuel with gas oil in the proportions 20, 40, 60, 80, and 100%, preheated to give a visc approx that of gas oil at 15° C. The gas oil contained 0·82% S and a trace of ash; the boiler fuel had the specifications $\eta = 492$ sec Red. I (100° F), S 2·04%, ash 0·02%. Each blend was tested on a 7-hr cycle, of which 6 hr were run at max cruising speed (6500 r.p.m.). With all except the 100% boiler fuel the performance and condition of the turbine did not materially differ from a run with gas oil. The test on 100% boiler fuel showed that the turbine could be so run for a limited period, but was not well suited to this fuel. Carbon build-up was heavy at idling and low power, but much less at high power.

The high-sulphur fuel contained 2·78% S, and its viscosity was similar to that of gas oil. Performance was similar to gas-oil tests, and although deposits were seen on dismantling there was no corrosion except on the jet shields, which were of high Ni content.

Further tests were made at various speeds with boiler fuel to examine carbon formation. It was found that at $>$ 5000 r.p.m. little deposit was formed; at 4000 r.p.m. some deposit was obtained, and at idling speed the deposit was serious. This could be burned off by running at normal speed on gas oil.

Tests were carried out with a fuel jet in which oil is forced through a central orifice

from a small swirl chamber, and air supplied by a compressor is fed through annular holes. At > 4000 r.p.m. the new jet did not affect the carbon deposits and the exhaust smoke; at 3000 r.p.m. there was much less exhaust smoke, but the carbon deposits remained indistinguishable from those obtained with the use of standard jets.

A 48-hr test comprising a continuous run on boiler fuel at max cruising speed (6500 r.p.m.) was followed by examination of the stripped engine. Carbon deposits were found in various places, but the turbine blading showed little deposit and no deterioration.

From these tests it was concluded that the engine could be used with boiler fuel and with gas oil without modification. The combustion system was not suited to the heavy fuel, particularly at idling speeds. H. C. E.

2574. Oxygen-enriched air in the combustion theory. F. Schuster. *Brennstoff-Chemie*, 1951, **32** (13–14), 206–13.—A classification scheme is presented to indicate the degrees of combustion of fuels with varying quantities of air. Air consumed is normal (*n*-air), and enriched (*a*-air). *A*-air is a mixture of *n*-air and pure or high-% oxygen. It is desirable often to represent the mixing relation by the amount of added oxygen per unit quantity of *n*-air. For all these concns of added oxygen curves are traced, from which the conversion of a concn estimate into any other one is possible. Combustion equations are constructed on the quantity relation between oxygen and air or nitrogen. A conversion table is given, therefore, for *a*- and *n*-air, which permits oxygen quantities in K mol, kg, or Nm^3-units to be converted to the corresponding air and nitrogen quantities. It is not correct to differentiate in the combustion calculation between solid and liquid fuels according to the state of aggregation. The difference is determined by the type rather than by the composition of the fuel. One group is derived from the elementary composition, and can be used for fuels of every state of aggregation. The other group rests on the volumetric composition, which applies to gaseous fuels alone. As examples of the fundamental combustion and gasification equations of carbon and hydrocarbons, a simplified combustion calculation for *a*-air and *n*-air, on the basis of the elementary composition, is derived. *A*-air affects the conditions between air excess and flue-gas composition, therefore equations for the combustion with and without foreign carbon dioxide are given. R. T.

2575. Evaluation of fuels using the Jentzsch ignition tester. R. B. Gilmer and H. F. Calcote. *Industr. Engng Chem.*, 1951, **43** (1), 181–4.—The characteristic ignition value of a number of pure hydrocarbons, mixtures, and standard fuels was determined using the Jentzsch ignition tester, and the results correlated with critical compression ratios given in the literature. The authors conclude that "as a means of attaching a single number to a fuel to indicate its tendency to knock the Jentzsch ignition tester is as adequate as any single engine test." F. M.

2576. New light on improving gasoline anti-knock quality. T. H. Risk and M. L. Alspaugh. *Oil Gas J.*, 30.8.51, **50** (17), 66.—Improvements in gasoline anti-knock quality can be achieved by three methods. First is reduction of end point of present stocks with sacrifice of gasoline yield; second, addition of purchased high-octane-number blending stocks to present production; and lastly installation of new equipment.

Conclusion is reached that installation of modern units is best solution.

Twenty-one figures illustrate anti-knock improvement by blending and by new processes, and four tables are also given. G. A. C.

Gas Oil and Fuel Oil

2577. Coal tar fuels. E. B. Davies. *J. Inst. Heating and Ventilating Eng.*, Sept. 1951, **19** (193), 262–76.—A brief review is given of British coal-tar distillation, and production figures of coal-tar fractions are recorded. B.S. Specifications for coal-tar fractions: C.T.F. 50, 100, 200, 250, 300, and 400 are given, and their chemical and physical properties are described. The general application of C.T.F. 200 to boilers is described, and burning-installation systems are illustrated. The combustion characteristics of this fuel and five types of burners are described. W. H. C.

Lubricants

2578. Special staff prescribes, follows up lubrication of refinery equipment. Anon. *Petrol. Process.*, 1950, **5** (10), 1070–1.—A condensed version is given of a paper entitled "Lubrication of refinery equipment," presented by F. M. Leverett before a Petroleum Mechanical Engineering Conference of the Amer. Soc. Mech. Engrs, New Orleans, Sept. 24–28. The value of the lubrication chart is stressed as a part of the lubrication programme of a large refinery. Typical examples of difficult refinery lubrication problems and means of overcoming them are outlined. D. W. F.

2579. Special lubricants tests. Anon. *Mech. Engng*, 1951, **73** (8), 657.—Static friction coefficients were determined for a number of lubricants in combination with various metals. Lowest coefficients were obtained by lubricants containing molybdenum disulphide, a mineral lubricating grease, dry molybdenum disulphide, and a fluorinated hydrocarbon with graphite additive. T. T.

2580. Non-soap lubricating greases. R. R. Matthews. *Petrol. Process.*, 1950, **5** (10), 1082–4.—The standard ASTM definition of a lubricating grease, D.288–49, is criticized on the grounds that it does not include thickened mineral oils containing no soap. Some of the currently available non-soap lubricating greases are listed and discussed. Revision of the definition is under consideration. D. W. F.

2581. Patents. Fr. P. 973,167, 8.2.51. Compt. Franç. de Raffinage. Utilization of shale oil for the production of lubricating oils, of chemical derivatives and of gas oil.

Ger. P. 800,423, 6.11.50. H. Petrovicki. Bad. Anilin- u. Sodafabrik. Production of greases from hydrocarbons, soap-forming organic compounds, and further acid materials by saponification with alkalis or alkaline earths or their mixtures. *Brennstoff-Chemie*, 15.8.51, **32** (15–16). R. T.

Bitumen, Asphalt, and Tar

2582. Control of hot-mix asphaltic concrete. J. R. Martin. *Rds & Streets*, July 1951, **94** (7), 80.—Control of asphaltic concrete means that the previously agreed design shall be reproduced in practice. The principles behind this design are as follows: (1) the aggregate must be reasonably well-graded; (2) the voids content should be about 4%; (3) the stability of the compacted mix should be determined; (4) the bitumen shall not be too hard. The stabilities of a number of mixes with different bitumen contents are determined, and a suitable bitumen content agreed, depending upon the type of traffic to which the finished concrete is to be subjected. The relationship between stability and type of stone (and hence cost) is also determined. The aggregate grading is also of importance. Details of plant control and field control are discussed, so that the design conditions are reproduced. R. H.

2583. Patents. Finnish P. 24,682, 30.11.50. M. Ilveskorpi. Surfacing material for roads. *Brennstoff-Chemie*, 15.8.51, **32** (15–16). R. T.

Special Hydrocarbon Products

2584. Battle against brush. A. E. Carlson. *Oil Gas J.*, 13.9.51, **50** (19), 127.—Spraying to control vines, brush, and trees growing alongside 112 miles of telephone lines across marsh lands, instead of hand cutting, has effected a saving of 71% in annual line-maintenance costs for the United Gas Pipe Line Co., La., U.S.A. After disappointing results first season, due to inadequate coverage, results next season with hormone sprays, 2 : 4-D and 2 : 4 : 5-T were very good. G. A. C.

2585. Patent. Ger. P. 812,787, 17.5.50. R. Hüttel u. W. Deckers. Tech. Chemie. Method for the production of hexachloro*cyclo*hexane.

Ger. P. 814,000, 26.7.51. W. Gundel u. W. Scherff. Henkel & Cie. Method for the production of hexahalogen-*cyclo*hexanes. *Brennstoff-Chemie*, 28.8.51, **32** (15–16). R. T.

2586. Methane chlorination using hydrogen chloride and oxygen. H. P. Meissner and E. F. Thode. *Industr. Engng Chem.*, 1951, **43** (1), 129–33.—Using hydrogen chloride and oxygen with either steam or nitrogen as inert, methane was chlorinated over a copper chloride catalyst in a 1-inch I.D. tube at temp around 400° to 550° C. A mixture of the four chloromethanes was obtained, the composition of which could be varied within wide limits by variation of the feed gas composition. Experimental results are tabulated showing that under suitable conditions almost complete conversion of hydrogen chloride to chlorinated products can be achieved with methane conversions of 10 to 40%. Using chlorine and air methane was chlorinated under similar conditions with satisfactory results. F. M.

2587. Monsanto Chemicals at Newport. Anon. *Paint Technol.*, Aug. 1951, **16** (188), 345.—A description of the new Monsanto factory at Newport, Mon., is given. It includes plants for making chlorinated diphenyl plasticizers, styrene, plastic, preservatives and fungicides, oil additives, and detergents. Brief mention is made of the offices, workshops, and welfare block. Several photographs are included. D. K.

Coal, Shale, and Peat

2588. Information on coal tar light oils. O. Kruber and A. Raeithel. *Brennstoff-Chemie*, 1951, **32** (15–16), 243–5.—The preparation and properties of some little-known materials produced from the fractions obtained in the distillation of coal-tar light oils (1·5% of the total tar) are described. *o*-Tolunitrile, 4-methylhydrindenes, *iso*durol, Prehnitol, 4-methylindenes, and paraffins of the dodecane series are discussed. R. T.

2589. Development of cumarone resin to the modern raw material of the varnish and paint industry. H. Wille. *Brennstoff-Chemie*, 1951, **32** (15–16), 238–43.—The most favourable source of coumarone resins, essentially coumarone–indole resins, is the crude benzole obtained from the gas produced in the high-temp coking of coal. The crude benzole is dist over an iron-oxide–soda catalyst, and the fraction boiling at 160° to 182° C is utilized. This solvent benzole fraction contains, in addition to coumarone and indole, di- and tri-methyl benzene, phenol, cresol, and pyridine homologues which are removed by washing. Besides indole, other unsaturated hydrocarbons, styrene (b.p. 145° C), and di*cyclo*pentadiene (b.p. 170° C) are present and are removed by preliminary polymerization with 60%-sulphuric acid. On heating, coumarone (b.p. 172° C) has a tendency to acetopolymerization, especially in the presence of acid reagents. In this respect *cyclo*pentadiene and styrene, which darken the polymer, and especially indene, by reason of its reactivity and unsaturated character, are similar. According to concn and conditions indole is sp for the degree of polymerization of the indole–coumarone mixture. By carefully controlled polymerization with 2 to 5 vol.-% sulphuric acid at 20° to 35° C the properties of hardness, transparency, and compatibility with solvents are assured. The catalyst is removed, the polymer washed and neutralized. Removal of the unpolymerized or low-polymerized portion is carried out by distillation. The resins are improved by pressure hydrogenation over nickel to saturation of the residual double bonds, thus avoiding the formation of fulvene, which produces a yellow colour. R. T.

2590. Classification and treatment of bituminous shale. S. Tertil. *Nafta*, June 1950, **6**, 165–71.—Bituminous shales can be divided into six groups, depending on their origin. Their elemental composition varies from 40 to 83% C. They are worked and treated in the U.S.S.R., Scotland, Manchuria, Sweden, France, Germany, Australia, Italy, and some other countries. Many useful products are obtained, as well as a high proportion of high-MW phenols. Cracking and hydrogenation may be employed on shale oils with success. M. S.

2591. Shale oil as a future source of energy in Western States. S. H. McAllister. *Petrol. Process.*, 1950, **5** (10), 1076–9. (*Previously presented before the N. California Section of A.C.S.*)—As petroleum reserves dwindle the possibility is presented of eventually having to rely on the reserves of coal and oil shale abundant in the Western States. So far shale oil has not been competitive economically with petroleum, but

the potential shale-oil reserves in Western Colorado and Eastern Utah of 300 (U.S.) billion brl amounts to about thirteen times the total proven U.S. petroleum reserves.

A brief description is given of the origin and nature of shale oil, together with the mining and retorting procedure currently in use at the demonstration plant, Rifle, Colo. Analysis figures for a raw shale oil are compared with those for a representative West Coast crude, showing that there is present little gasoline and light naphtha, it is high in nitrogen and sulphur, but deficient in hydrogen, and is rich in cyclic and olefinic compounds. An acceptable bunker fuel could be produced after relatively little processing, but vis-breaking would be required before it could be pumped to refining centres for further treatment. Possible methods of refining are outlined.

On the Pacific Coast oil from shale appears to have better future economic possibilities than oil from coal, it being estimated that the shale oil could be produced at below $2/brl at the Rifle plant. Approx estimated costs of manufacture are given as 19·5 c/gal, as compared with 14·5 c from petroleum, 12·5 c from natural gas, and 21·5 c from coal. D. W. F.

2592. Study of preheating Colorado oil shale. W. E. Robinson and A. B. Hubbard. *Bur. Mines Rep. Inv. No.* 4787, Apr. 1951.—Details are given of an investigation to ascertain whether drying or preheating Colorado oil shale with waste retort gases appreciably affected its oil yield on retorting. The results showed that preheating the oil shale in the presence of nitrogen or a non-oxidising mixture has no effect upon the oil or water yield. The oil yield is, however, lowered by increasing the oxygen content of the preheating mixture, by increasing the temperature of the preheating gas, by increasing the shale residence time, and by decreasing the particle size of the shale. The decrease in oil and increase in water yield result from the oxidation of the benzene-insoluble material (kerogen), rather than from the oxidation of the benzene-soluble material (natural bitumen) in the shale. The merits and disadvantages of commercial application of drying and preheating are discussed. It is concluded that with proper heating conditions waste heat from the retorting for preheating and drying can be employed without appreciably affecting the oil yield. W. H. C.

Miscellaneous Products

2593. Neoprene applications in engineering design. R. W. Malcolmson. *Mech. Engng*, 1951, **73** (8), 627.—Neoprene is claimed to be superior to natural rubber with respect to compression set, flame and heat resistance, permeability to gases, and weathering and ageing, while the harder grades have greater resilience and lower hysteresis. Short-term creep tests show neoprene at a disadvantage, but long-term tests indicate that the creep resistance of neoprene approaches that of natural rubber. The hardness of neoprene increases at temperatures below 10° F. As a dielectric, neoprene is inferior to natural rubber. Neoprene gives good service in contact with straight-chain hydrocarbons, animal and vegetable oils, aliphatic hydroxy compounds, and most "Freon" refrigerants, but is unsuitable for use with chlorinated hydrocarbons, organic esters, aromatic hydrocarbons, and some ketones. Numerous applications of neoprene are reported. T. T.

2594. Engineering properties of silicone rubbers. P. C. Servais. *Mech. Engng*, 1951, **73** (8), 639.—Silicon rubbers are distinguished by a retention of rubber-like properties at temps above and below the serviceable limits of natural and synthetic organic rubbers, certain types being serviceable from −110° to 500° F. Tensile strength and elongation are low compared with natural rubber at room temp, but are little affected by high or low temps. As a dielectric material, silicone rubber is stable at high temps. The price of silicone rubber is several times that of organic rubbers, but it is intended to operate at temps beyond the scope of other elastomers. T. T.

2595. Detergency properties of systems containing a solid nonionic detergent. H. R. Suter and M. G. Kramer. *Soap Sanitary Chem.*, Aug. 1951, **27** (8), 33.—Further data on the properties and uses of the new range of solid non-ionics known as Pluronics. The grade F68, with a melting point of 51° to 54° C, can be used to prepare free-flowing dustless products. Article is mostly concerned with three-component systems, consisting of solid non-ionic, alkyl aryl sulphonate anionic and C.M.C., tested for cotton

washing using artificial soils, laboratory technique, and evaluation of soil removal and whiteness retention by established methods. A set of tests is also included in which tripolyphosphate builders are given. For each ternary system, both distilled and hard water is used, the results being shown as ternary graphs. With hard water, both the carbon-soil-removal and whiteness-retention graphs showed maximum results in a closed area, indicating that within that area the three-component systems gave the greatest advantage. From these diagrams a general formulation was determined, consisting of 30% organic detergent (40% Pluronic, 40% alkyl aryl sulphonate, 20% C.M.C.), 45% sodium tripolyphosphate, 25% soda ash. N. W. G.

2596. Detergent sanitizers. M. A. Lesser. *Soap Sanitary Chem.*, Aug. 1951, **27** (8), 37.—These products, sometimes known as germicidal detergents, have a two-fold function indicated by the latter name—as a cleaner and as a germicide (and sometimes as a deodorant). This article is a literature review of these products, which were used widely during the war in military camps and now in dairies, for dish washing, etc. The quaternary ammonium salts are themselves dual purpose, and much of the early work was developed using them. Newer products compound the quaternaries with other detergents to assist in emulsifying greases and to promote free rinsing. Most examples of compounded products quote non-ionics. Both quaternaries and non-ionics have optimum conditions slightly on the alkaline side, so that formulations usually contain a condensed phosphate or other mild detergent. Further products are quoted, in which anionics are combined with germicides, such as para-chloro-*m*-xylenol.
N. W. G.

2597. Solvent-detergent products. A. Davidsohn. *Soap Sanitary Chem.*, Aug. 1951, **27** (8), 47.—In addition to the older uses for dry-cleaning soaps and spotting soaps, these products are now used as degreasing agents in the metal industry and as solvent emulsifiers for insecticides. This article describes blends using anionic detergents (dodecyl benzene sulphonate) in place of the older sulphonated castor oil. High levels of anionic give blends which can be diluted with both water and solvent, but at lower levels stable emulsions with water are given. These products can be used both with hard water and builders. Combination products discussed cover soap–anionic blends and alkyl aryl sulphonate–non-ionic blends. N. G. W.

2598. Built detergent performance. H. Stupel and A. von Segesser. *Soap Sanitary Chem.*, Aug. 1951, **27** (8), 79.—This is a summary of a paper in *Soap Perfumery & Cosmetics*, 1951, **24** (6), 558, dealing with the influence of various factors on soil removal using a built heavy-duty detergent based on secondary alkyl sulphates. The inorganic builders accounted for 25% of the formula, being made up of phosphates (pyro- and tripoly-), borates, and metasilicates. The factors tested included pH (optimum at 9·5 to 10·5), water hardness (increase of hardness decreased detergency), builders (particularly condensed phosphates, which gave an improved detergency greater than the water-softening effect), optical bleaching agents, dirt-suspending agents (carboxymethylcellulose), and fillers. The results were that the heavily built detergent tested, compared with soap, showed the detergency power of synthetics was greater than that for the fatty acid soap. This was shown by both laboratory and practical trials. N. G. W.

2599. Evaluation of liquefied-gas aerosols. R. A. Fulton, R. H. Nelson, and A. H. Yeomans. *Soap Sanitary Chem.*, Aug. 1951, **27** (8), 129.—This article contains details of some of the testing techniques used for aerosols at the U.S. Department of Agriculture :—

(*a*) The specification for particle size requires 80% less than 30 μ with no particles greater than 50 μ. Methods of collecting samples on slides, both by hand waving and impactors driven by variable speed motors, were tested.

(*b*) Due to the effect of solvents on valve-seat materials, these are tested at 32° to 120° F and with the valve in two positions, up and down.

(*c*) For biological evaluation, the Tentative N.A.I.D.M. Aerosol Test Method for Flying Insects is used. N. W. G.

2600. Interaction between carbon black and polymer in cured elastomers. R. S. Stearns and B. L. Johnson. *Industr. Engng Chem.*, 1951, **43** (1), 146–53.—It is shown by a study of the thermodynamic changes accompanying the deformation of loaded stocks that physical adsorption of the carbon black on the polymer surface does not adequately account for the experimental observation. Reaction between carbon black and bromine was shown to liberate the same amount of heat as the reaction between bromine and low-mol.-wt. olefins. A polymeric benzenoid-type molecule having functional groups around the perimeter is suggested as a possible structure of carbon-black particles. The existence of olefinic unsaturation in the carbon black suggests that chemical bonding between polymer and pigment occurs between these olefinic double bonds and sulphur of the polymer. F. M.

2601. Oil soluble phenolic resins. R. N. Shreve and B. Golding. *Industr. Engng Chem.*, 1951, **43** (1), 134–41.—The use of phenol–formaldehyde condensation products in oleoresinous varnishes has been investigated, with particular reference to resins made from para-substituted phenols. Experimental data are listed of the oil solubility, oil reactivity, colour stability, drying rate, resistance to moisture, etc., for many resins. F. M.

2602. Pentaerthyritol alkyds. Some theoretical considerations. A. G. North. *Paint Technol.*, Aug. 1951, **16** (188), 333.—The use of penta-erythritol in alkyds is considered from the aspects of prediction of alkyd behaviour and comparison of predicted with practical results. A brief résumé is given of the chemistry of penta-erythritol. Lynas-Gray has illustrated comparative degrees of cross-linking in penta- and glycerol alkyds of the same oil length by means of an equation. The usefulness of cross-linking calculations is considered. The variables to be considered in these calculations are distribution of monofunctional modifiers; excess of polyhydric alcohol; loss of reactants; side-reactions; and extent to which reaction is complete. The effect of cross-linking on the behaviour of alkyds is discussed. The alkyds are considered as three main classes, air-drying, stoving, and plasticizing types. The practical applications are discussed. D. K.

Corrosion

2603. Corrosion and its control. M. E. Parker. *Oil Gas J.*, 23.8.51, **50** (16), 163; 30.8.51, **50** (17), 89.—Pt 25 in this series deals with corrosion instruments for determination of soil resistivity; and flow sheets for a four-terminal method, and an alternating-current bridge for use with one-rod soil-resistivity apparatus is given.

Pt 26 concerns measurements of line currents by a high-resistance voltmeter or a potentiometer. A formula is given for correcting the voltmeter reading, but this is not applicable to the potentiometer, nor can that instrument be used in the measurement of fluctuating currents where the pipe is under influence of stray currents. Test leads and a high-resistance instrument should be employed in such cases. G. A. C.

2604. Corrosion and its control. M. E. Parker. *Oil Gas J.*, 6.9.51, **50** (18), 111.—Coating inspection in the field covers materials handling and storage, equipment, application techniques, testing and repairing, and handling of coated pipe. Efficient inspection will save considerable expense in cost of cathodic protection. G. A. C.

Engines and Automotive Equipment

2605. Burners for supersonic ram-jets. Factors controlling over-all burner performance. J. W. Mullen, II, J. B. Fenn, and R. C. Garmon. *Industr. Engng Chem.*, 1951, **43** (1), 195–211.—Experimental results are presented on the effect of air–fuel ratio, mixture condition, igniter geometry, inlet-air temp, combustion-chamber length, and air-mass flow on burner efficiency. The experiments were conducted using a connected pipe burner 2 inches in dia, supplied with sufficient air to simulate sea-level flight at Mach Number of 1·5 to 2·0. Burner performance was evaluated in terms of air specific impulse. *n*-Pentane, mixed hexanes, and kerosine (ANF. 32) were the fuels used, and tabulated data for these fuels and all the variables tested are given. Forty-one literature references are included. F. M.

2606. Variable compression ratio supercharging. R. Miller. *Motor Ship*, Sept. 1951, **32** (378), 232.—The paper gives an analysis of the effects and advantages of the Miller system of supercharging. It is an extract from a paper given by the author at the Gas and Oil Conference, Dallas, in June 1951, on the effect of charge temp and pressure on rating of diesel engines and a variable C.R. supercharging system for two- and four-cycle internal-combustion engines. Experimental research is reported which was carried out in order to determine the effect of pressure and temp changes upon engine output. In this way a method of predicting by simple calculations the mean effective pressure obtainable within pre-determined engine-temp and pressure limits was developed. U. M.

2607. Gas-turbine centrifugal compressor stations. J. F. Eichelmann and J. S. Quill. *Oil Gas J.*, 6.9.51, **50** (18), 81.—The first large-scale installation of gas-turbine-driven compressor stations for natural-gas pipelines to be undertaken by El Paso Natural Gas Co. is described. It will be necessary to instal seven 5000-h.p. stations for the first 100 million cu. ft/day increase in delivery capacity of the line and eighteen additional units for future 200 million cu. ft/day increase. G. A. C.

MISCELLANEOUS

2608. Third World Petroleum Congress. Anon. *Nature*, 1951, **168**, 190.—A summary of the meeting held at The Hague, May 28–June 6, 1951. At the sixty sessions nearly 200 papers were presented.

The Congress is here summarized under the following headings: Geology and geophysics, Drilling and production, Physical refining processes, Chemical refining processes, Petroleum chemicals, Composition of petroleum, Utilization, Construction materials, Miscellaneous. H. C. E.

2609. Cost estimating simplified. C. H. Chilton. *Chem. Engng*, 1951, **58** (6), 108–11.—The procedure for producing quickly cost estimates from a projected process is given simply and directly, with special attention to details that are easily overlooked. The composite costs of operating, overheads, depreciation, administration, research, and taxation are tabulated, and the best source of data on each item is given. A method of calculating net return on invested capital and a simplified formula for selling price is given. D. H.

2610. Achievements in post-war period and projects for the six-years plan of the Polish natural gasoline industry. A. Kahl. *Nafta*, July 1950, **6**, 192–7.—From natural gas the fractions C_3 to C_6 can be separated by compression absorption or adsorption. The Polish industry uses mostly the last method. From crude oil the same fraction is obtained by stabilization (or topping) by taking crude from the well in an air-tight pipeline to a topping column where the temp is kept between 60° and 100° C. By removal of C_3 and C_4 stabilized natural gasoline is produced as well as propane, butane, and any C_1 and C_2 which may have been there in solution. Gaseous mixture is used as fuel, C_3 for deasphalting and C_4 for the chemical industry and as fuel.

Before and under German occupation over 6000 tons p.a. of gasoline were produced. During their withdrawal in 1943–45 the enemy destroyed the equipment, and excessive exploitation lowered the formation pressure from 90 atm to 20 atm. When the industry was restarted the Grand Plan was put into operation and new plants were built. This formed a three years' plan, which was fully achieved. More gasoline was obtained from natural-gas wells and less from crude-bearing wells. The six years' plan intends further expansion of plant facilities and increase of their efficiency, with special consideration for propane extraction and cutting losses. M. S.

2611. Benzene from petroleum. How? And how much? G. Egloff. *Oil Gas J.*, 6.9.51, **50** (18), 96.—A review of sources of benzene production is given, and a number of tables illustrate consumption and requirements of chemical-grade benzene, estimated annual requirements until 1955, projected capacity, and quantities of aromatics from Platforming on a 1951 and a 1955 basis. G. A. C.

BOOK REVIEWS

Fundamentals of Automatic Control. G. H. Farrington. London: Chapman & Hall, Ltd, 1951. Pp. xii + 285. 30*s*.

Information on the new science of automatic control is scattered through technical journals and periodicals, and, as yet, very few comprehensive books are available. For this reason, and also on its own merits, this book is an important contribution, and should establish itself as a standard reference book for those interested in the theory of automatic control application.

Though the author cites one or two specific applications as examples, he does not deal with particular plants or instruments. The fundamental theory of automatic control applications is studied, and the book deals with general and basic problems and principles. In this task the author has frequently considered it necessary to adopt a highly mathematical approach largely based on electrical analogies, which, unfortunately, may prove discouraging to the practical engineer.

Electrical analogues for automatic control systems are developed, and, in applying these, and in his mathematical analyses generally, the author has made clear the nature and implications of his simplifying assumptions, so that there can be no doubt about the differences between theory and observed actual performance.

The main types of control receive clear treatment, and hunting-control vector diagrams are given for single and combined actions. The application of proportional, integral, and derivative control to closed-loop systems is discussed, and polar diagrams are worked out for plants having different numbers of stages. This is carried farther in later chapters, and polar charts are developed, giving iso-damping and iso-frequency curves.

Chapter V dealing with changes of load and desired value gives a particularly good picture of the differing effects of demand changes and supply changes on proportional, derivative, and integral control and combinations. The initial ineffectiveness of control with certain demand changes is well illustrated, but it is a pity that so little attention is paid to the effect of load on the plant characteristic.

In Chapter VI the permissible length and diameter of pneumatic transmission lines are worked out for given frequencies and desired limits of attenuation and phase shift.

Though stressing the importance of the final regulating unit, the author does not deal with this important subject in a very satisfactory way. He confines himself to the exceptional case where there is constant pressure drop across the valve.

In Chapter XI there is an excellent analysis of controlling units, giving methods by which various control actions can be obtained and dealing with the problems of control interaction. Derivative stabilization is mentioned, together with its effect in producing a lag in the true phase.

It is unfortunate that there was no opportunity in this book to discuss C. I. Rutherford's paper to the Institution of Mechanical Engineers on "The practical application of frequency response analysis to automatic process control." Perhaps this will be included in future editions.

In the final chapter, dealing with control selection and adjustment, the practical limitations of the book are made obvious. So many factors are involved in the application and adjustment of automatic control systems that mathematical analysis cannot as yet provide many of the answers. In practice, automatic control application is, even to-day, more of an art than a science. Theory is of assistance to experience and judgment, but cannot replace these rare qualities.

J. C. F.

Storage of Petroleum Spirit. H. E. Watts. London: Charles Griffin & Co. Ltd., 1951. Pp. 320. 28*s*.

This book has been written primarily for the guidance of local authorities and their officers who may be concerned with the conveyance and storage of petroleum spirit in their areas. As a book of reference it will undoubtedly prove valuable for this purpose and should go a long way towards ensuring uniformity of good practice.

The first chapter contains some useful definitions and explanations of various terms and descriptions used in the petroleum industry.

Chapter II deals generally with the origin and properties of petroleum and the methods of producing oil, and refers to allied substances which come within the definition of petroleum spirit.

The Petroleum Consolidation Act (1928) is referred to in Chapter III, and the provisions of the Act are explained section by section. The sections of the Act dealing with the transport of petroleum spirit are considered, and the various regulations and suspension orders which have been made from time to time are listed and their provisions explained and commented upon.

Chapter V details the circumstances in which it is permissible to keep petroleum spirit without a licence and sets out the regulations that must be observed to do so.

Some good advice to users of petrol is given on pp. 65–7.

The procedure to be followed for obtaining a licence for keeping petroleum spirit and the method of appeal open to the applicant if the licence is refused, or granted subject to unacceptable conditions, are explained.

The author divides the licensed premises into three classes: namely, (1) the large bulk depot supplied by ocean tankers or, alternatively, large refineries; (2) distributing depots; and (3) the filling station where petrol is sold to the public.

Conditions for licences for each of the three classes of depots are discussed, and the reasons for their inclusion in the licence considered.

The recommended precautions to be observed at filling stations are described in considerable detail.

The sections dealing with the licensing of distributing depots, bulk-storage depots, and refineries contain much useful information for the guidance of licensing authorities, and describe many features which are recognized as good practice in the industry to-day.

In the section dealing with accidents, the author has described a number of accidents, many of which were caused by the failure of those involved to observe simple precautions necessary in handling petroleum spirit. Many were undoubtedly due to the ignorance of the hazards involved by the persons concerned.

Some useful information is given on the life and testing of underground tanks, and particular attention is drawn to the hazards involved in cleaning tanks which have contained leaded petrol unless suitable precautions are observed and rigidly enforced.

There is a further passage on various types of pumps and pumping systems as installed at filling stations.

The Appendixes include the Petroleum Consolidation Act (1928) and various codes and regulations that have been drawn-up controlling the transportation and testing, etc., of petroleum spirit and allied products.

This volume will provide a very useful book of reference for local authorities' officers and for all those engaged upon the storage and conveyance of petroleum spirit. J. K. F.

British Petroleum Equipment. 3rd Edn. London: The Council of British Manufacturers of Petroleum Equipment, 1951. Pp. 751. £2 2*s*.

The growth of this publication of the CBMPE from 524 pages in the second edition (1949) to 751 pages in the present edition is a welcome indication of the advances which British manufacturers are making as suppliers of equipment to the petroleum industry.

So diverse are the requirements of the petroleum that the classified list of products supplied by members of the Council occupies thirty-six pages of small type. These products are divided under some 300 main headings and close on 2000 subheadings. They range from complete plants to cinema equipment, from refrigerators to footwear, in fact everything required on an oilfield, in a refinery, or wherever oil is produced or handled. An alphabetical index to the classified list is provided.

Not the least important part of this book is the 686 pages of displayed announcements by members, an increase of over 200 pages over the previous issue. Here is given an considerable amount of technical and other information of value to the prospective purchaser and to the engineer in the field or refinery. At a glance he

can see the type of equipment available and much data regarding sizes, performance, etc.

The book is to be recommended as a useful guide to British equipment for the petroleum industry. G. S.

ADDITIONS TO THE LIBRARY

1951 SAE Handbook. New York: Society of Automotive Engineers, 1951. Pp. 864.

This latest edition of the SAE Handbook has been entirely reset in a larger format, which makes for ease of reading of tables.

The entire crankcase oil classification has been revised by eliminating the SAE 10 grade and including the 5 W, 10 W, and 20 W grades. Thus, there are now seven SAE grades: 5 W, 10 W, 20 W, 20, 30, 40, and 50.

Information is also given on the temperatures for recommending crankcase oils, on crankcase oil viscosities, on definitions of crankcase oils, and in engine tests for evaluating such oils. Transmission and axle lubricant classification is the same as in the previous edition, but the general information on these and on gear lubricants was revised in January 1951. Tables are given of corresponding viscosity ranges in CS, Redwood, and Engler units.

British Standards. London: British Standards Institution, 1951.

B.S. 767: 1951. Hydro-extractors and Centrifugal Machines. Pp. 15. 2*s*. 6*d*. net, post free.

B.S. 1721: 1951. Portable Fire Extinguishers of the Carbon Tetrachloride Type. Pp. 32. 4*s*. net, post free.

B.S. 949: 1951. Sewing Taps. Pp. 146. 15*s*. net, post free.

B.S. 609: 1951. Horizontal Multitubular Boilers of Riveted Construction. Pp. 47. 6*s*. net, post free.

B.S. 1674: 1951. Methods of Mixing and Vulcanizing Rubber Test Compounds. Pp. 14. 2*s*. net, post free.

B.S. 1767: 1951. Grommets for General Purposes. Pp. 11. 2*s*. net, post free.

B.S. 537: 1951. Lancashire and Cornish Boilers of Riveted Construction. Pp. 41. 6*s*. net, post free.

B.S. 665: 1951. Vertical Cross Tube Boilers of Riveted Construction. Pp. 41. 6*s*. net, post free.

THE INSTITUTE OF PETROLEUM

NOTICES, NOVEMBER 1951

ENTRANCE FEES AND SUBSCRIPTIONS

The current Entrance Fees and Annual Subscriptions for membership of the Institute are :

	Entrance Fee	*Annual Subscription*
	£ *s.* *d.*	£ *s.* *d.*
Members and Fellows	2 2 0	4 4 0
Associate Members and Associate Fellows .	1 1 0	3 3 0
Student Members	Nil	1 1 0

APPLICATIONS FOR MEMBERSHIP OR TRANSFER

The following have applied for admission to or transfer of membership in the Institute. In accordance with the By-laws, the proposals will not be considered until the lapse of at least one month after the publication of this *Journal*, during which time any Fellow, Member, Associate Fellow, or Associate Member may communicate by letter to the Secretary, for the confidential information of the Council, any particulars he may possess respecting the qualifications or suitability of the candidate.

The object of this information is to assist the Council in grading the candidate according to the class of membership.

The name of candidates' proposers and seconders are given in parentheses.

Application for Membership

BOLT, John Angus, fuel oil representative, Shell-Mex & B.P. Ltd. (*R. J. Bressey; T. C. Bailey.*)

BRACKENBURY, Peter S., technical advisor, Ministry of Supply. (*P. M. Griffiths; C. Hull.*)

BROWNLOW, Richard Derwent, student, University of Manchester. (*W. B. McCall.*)

CARTMEL, Bryan Spencer, Group Captain, R.A.F.

CHASTELL, Leonard Edward, draughtsman, Anglo-Iranian Oil Co. Ltd. (*R. E. Adlington; J. W. Fisher.*)

CLARK, Colin Evelyn, assistant development engineer, Anglo-Iranian Oil Co. Ltd. (*C. E. Evans; M. A. L. Banks.*)

DAVIES, Richard Hargreaves, plant supervisor, Apex (Trinidad) Oilfields Ltd. (*H. C. Costelloe; H. W. Reid.*)

DE VERTEUIL, Basil Joseph, head production foreman, United British Oilfields of Trinidad Ltd. (*R. Mackilligin; B. Brown.*)

FRENCH, Keith Harold Vernon, senior research chemist, National Benzole Co. Ltd. (*G. Claxton; R. G. Green.*)

GRIFFITHS, John George, instructor in Petroleum Technology, National Oil Refineries Ltd. (*P. F. Ellis; E. J. Horley.*)

JEWELL, Joseph Warren, sales engineer, Kellogg International Corporation. (*J. E. Lytle; R. C. Thomson.*)

JONES, Peter, process development chemist, National Oil Refineries Ltd. (*E. S. Squire; E. J. Horley.*)

LAVAL, Reginald Leslie Dennis, technical assistant, Messrs. C. C. Wakefield & Co. Ltd. (*N. E. F. Hitchcock; P. W. M. Gossling.*)

MCCORMACK, John Martin Gerald, chemist, Messrs. Wl. Ryan Pty. Ltd. (*H. A. Ruffell; L. O. Shiels.*)

MINA, Parviz, research student, University of Birmingham. (*F. H. Garner; F. Morten.*)

ROUSSEAU, Pierre Etienne, managing director, S. A. Coal, Oil and Gas Corporation Ltd. (*A. P. Faickney.*)

SLADE, Harold William, senior engineer, Shell Petroleum Co. Ltd. (*W. S. Ault; D. L. Samuel.*)

THOMSON, Eric, well pulling supervisor, United British Oilfields of Trinidad Ltd. (*R. Mackilligin; B. Brown.*)

WATSON, Arthur, fuel and lubrication officer, Ministry of Supply. (*A. Towle; G. H. Kinner.*)

Transfers

FOTHERGILL, Colin Arnold, university assistant lecturer in geology, Imperial College, London. (*S. E. Coomber; G. D. Hobson*) (*Student to Associate Fellow.*)

HOPKINS, Edric, petroleum plant operator, Anglo-Iranian Oil Co. Ltd. (*P. F. Ellis; E. J. Horley*) (*Student to Associate Fellow.*)

JONES, Glyndwr, superintendent (Process Plant), Manchester Oil Refinery Ltd. (*H. Kaye; C. E. Hobley*) (*Student to Associate Fellow.*)

SHIELS, Leo Osmonde, lubrication engineer, Texas Co. Aust. Pty. Ltd. (*H. A. Ruffell; R. Green*) (*Associate Member to Associate Fellow.*)

SPOTTISWOODE, John Nott, petroleum plant operator, Anglo-Iranian Oil Co. Ltd. (*P. F. Ellis; E. J. Horley*) (*Student to Associate Fellow.*)

NEW MEMBERS

The following elections have been made by the Council in accordance with the By-laws.

Elections are subject to confirmation in accordance with the By-laws.

As Fellows

BEVAN, H. G. M.
CATANHEDE, P.
HULME, J. A.
OLD, C. H.

As Members

DUGGAN, J. D.
GREGORY, R. K.
POCOCK, H. R. S.
RICHARDSON, F.

As Associate Fellows

ANDERS, O. C.
ARCHER, M.
BANERJEE, D. M.
BASHOURAN, A.
BERGIN, B. R.
BLIGHT, R. D. H.
BOWEN, I. G.
GIBSON, D. S.
HAWKINS, H. C.
HIBBLE, P.
HOWE, D. W.
JOYCE, R. G.
KAPUR, D. V.
KENDRICK, J.
KUMAR, R.
LE PAGE, J. L.
MAJOR, S. V.
MARRIOTT, I. S.
MELTON, B.
PRANCE, H. W.
SAW, W. W.
TAYLOR, N. W. O.
THREADGOLD, P.
TOURRET, R.
TRESIDDER, C. G.
WHITE, W. R.
WHITGRAVE, H. J.

Transferred from Associate Member to Associate Fellow

STEPHENSON, M.

Transferred from Students to Associate Fellows

COSSIN, D.
GOODMAN, L.
THISTLETON, P.

As Associate Members

BILTON, D. P.
BURTON, S. W. G.
EKSERDJIAN, N. M.
GILL, A.
HARTNELL-PARKER, B. K.
HARVEY, F. C.
HUNTLEY, E.
JONES, H. M.
LLOYD, R. R.
MALCOLM, R. S.
PARKINSON, H.
STANLEY-CARY, E. N.
TREWEEK, J. L.
WHALEBONE, E. C.

Transferred from Students to Associate Members

BENJAMIN, T. E. A.
WATSON, A. L.

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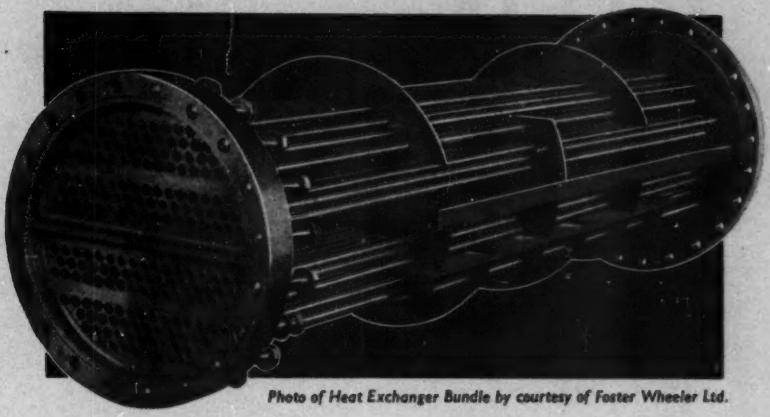

Photo of Heat Exchanger Bundle by courtesy of Foster Wheeler Ltd.

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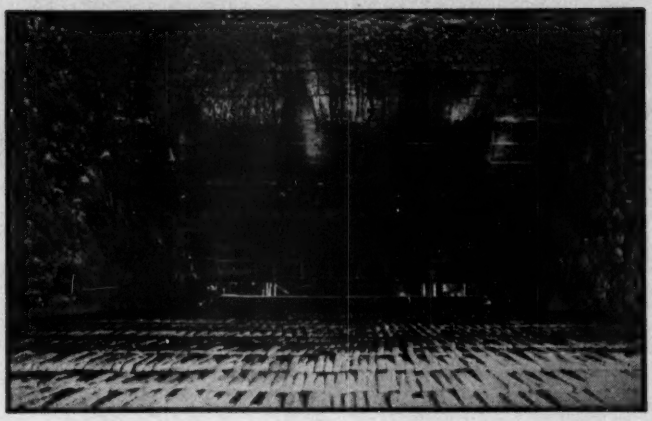

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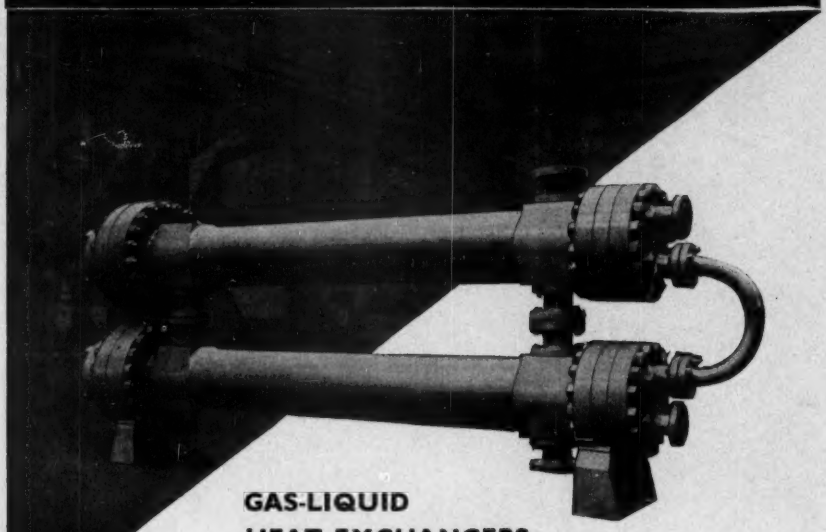

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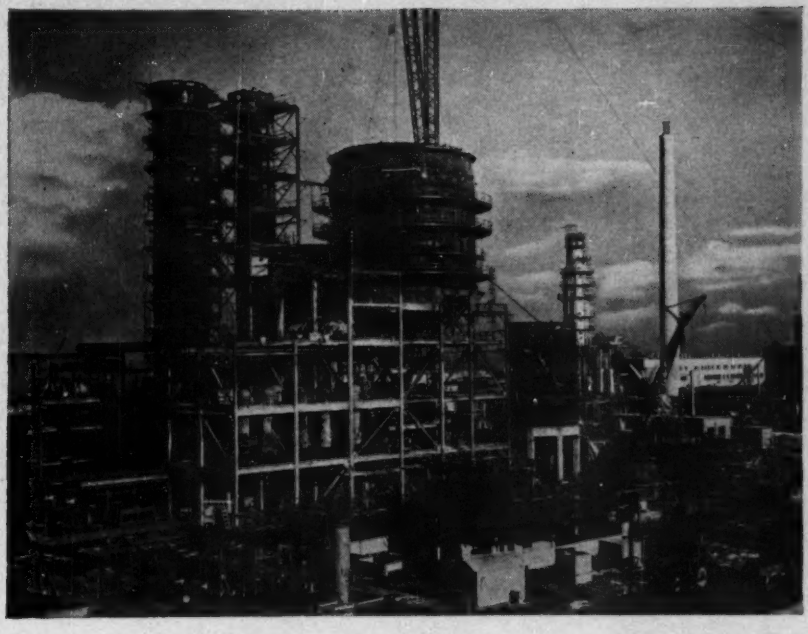

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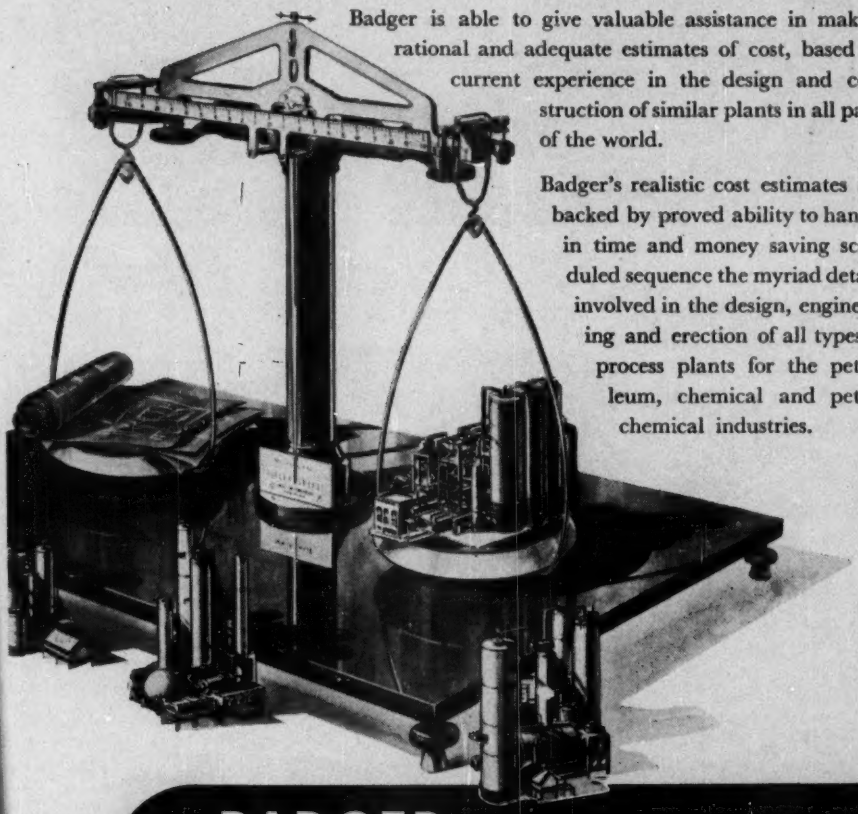

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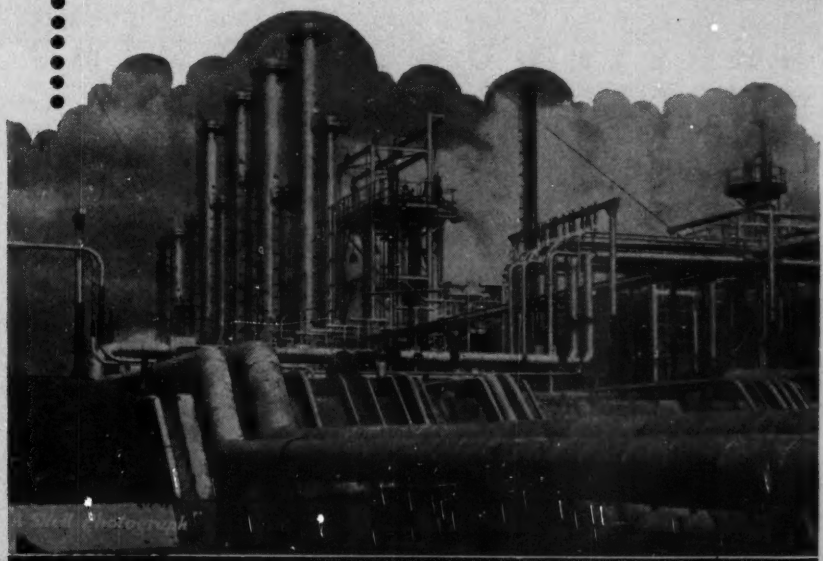

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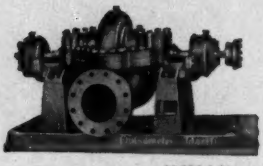

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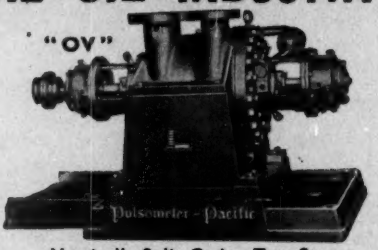

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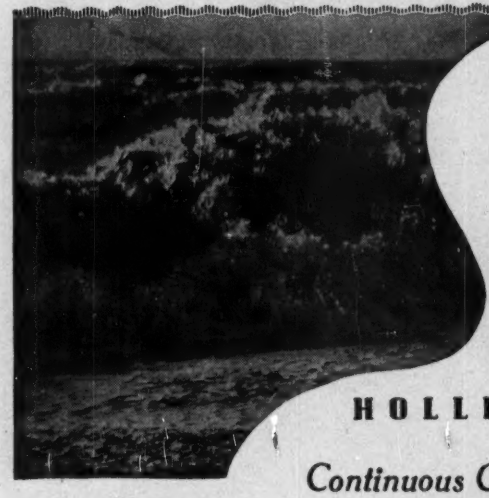

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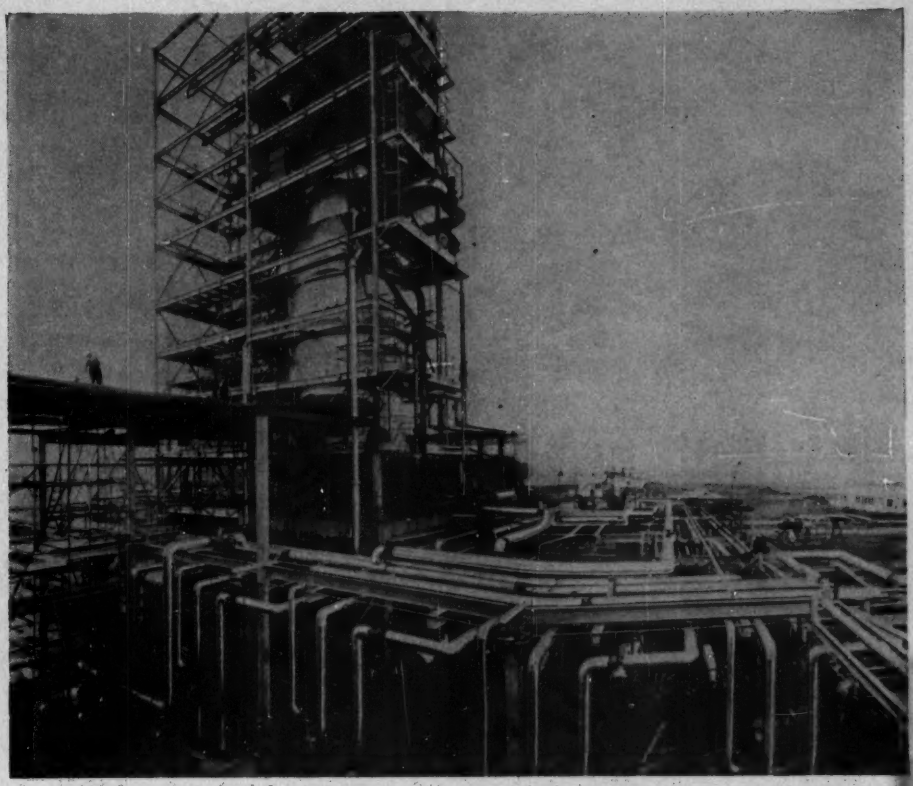

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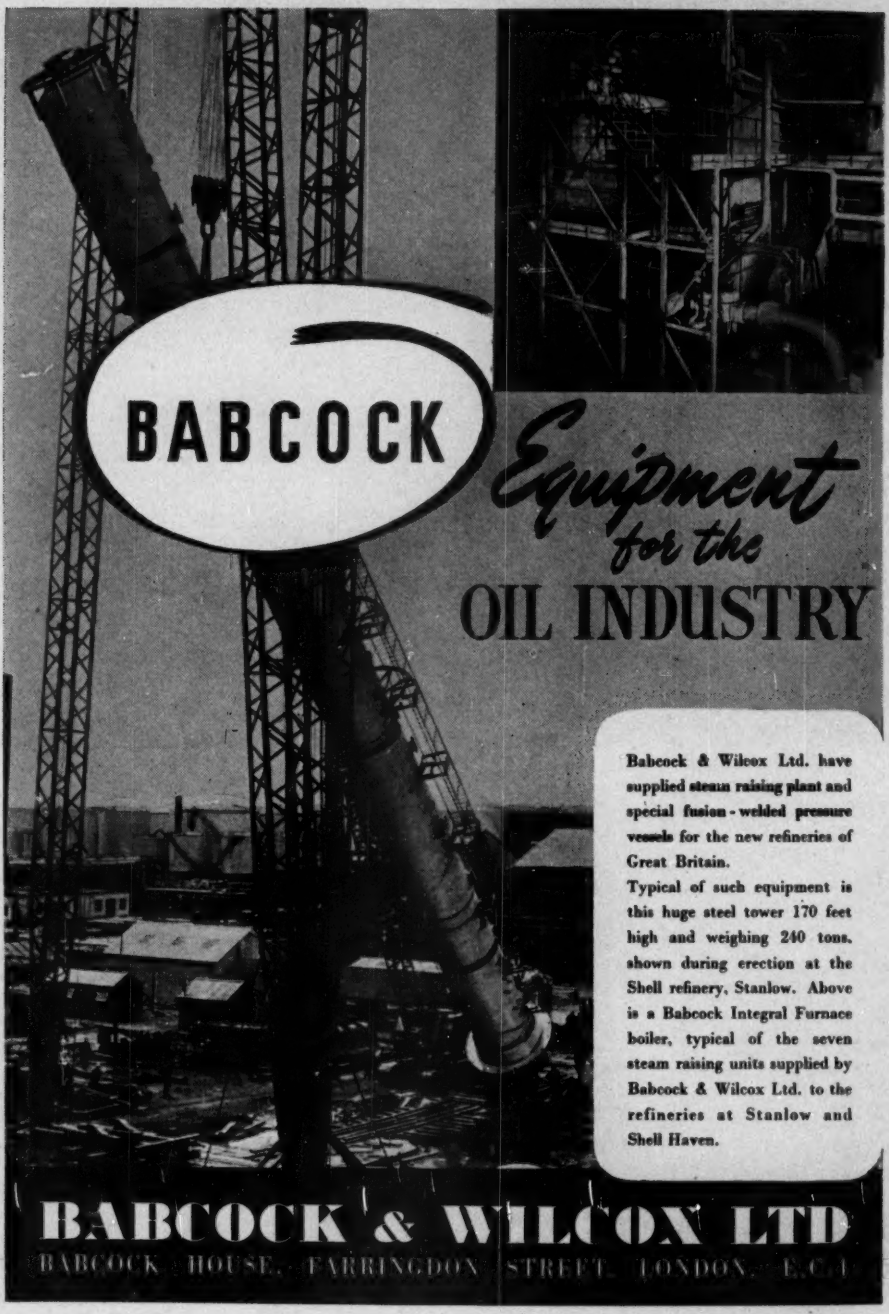
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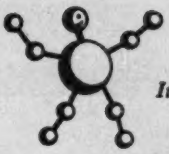

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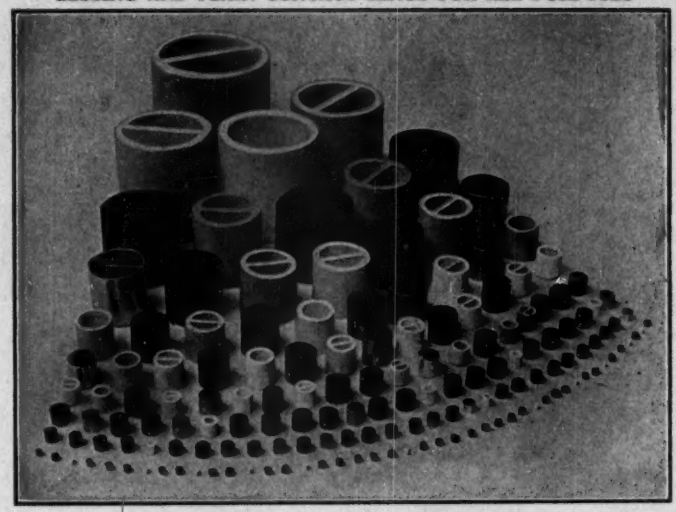

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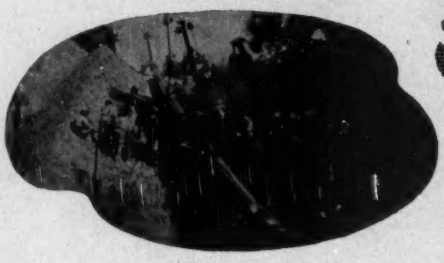

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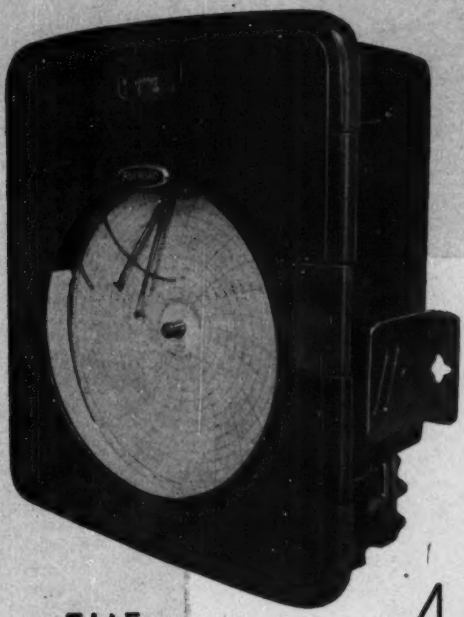

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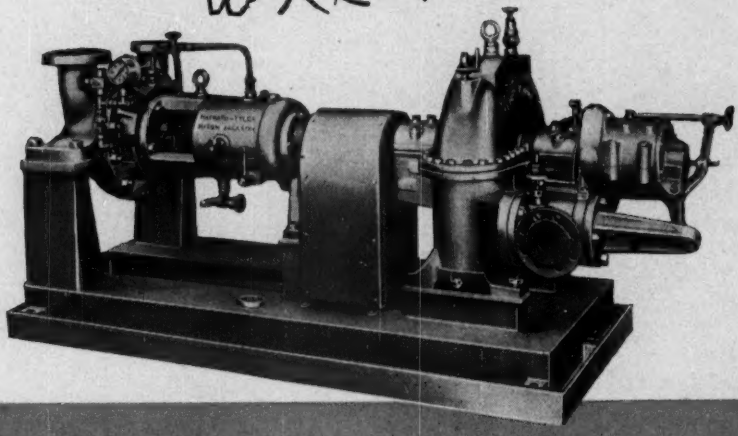

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Type and Class	Standard	Water Cooled Bearings	High Temperature	Standard
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Governor Valve Body	H.T. Cast Iron	H.T. Cast Iron	Cast Steel	Cast Steel
Max. Steam Pressure P.S.i.g.	250	250	250	450
Max. Steam Temperature °F	450°	530°	590°	750°
Max. Exhaust Pressure P.S.i.g.	50	50	50	60
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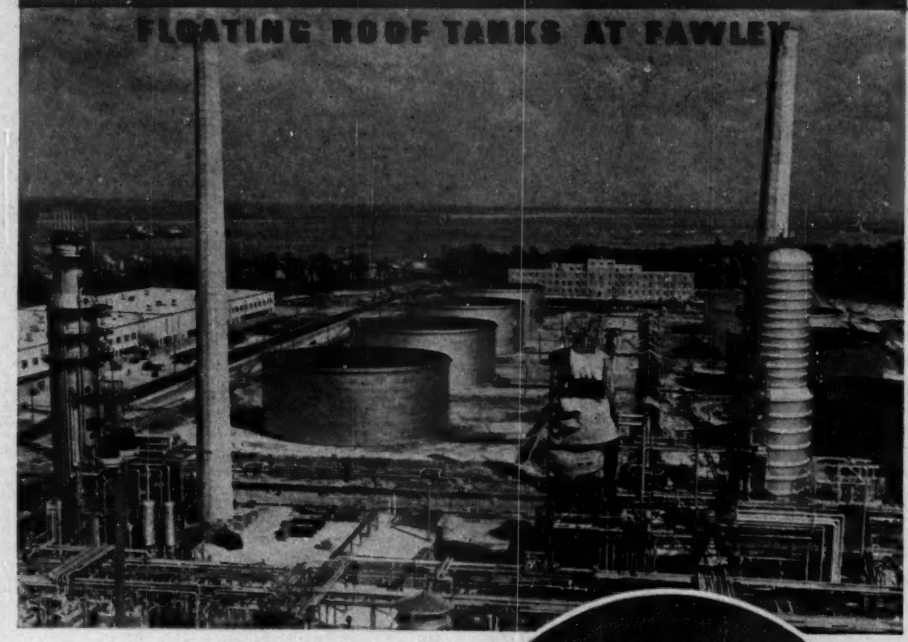

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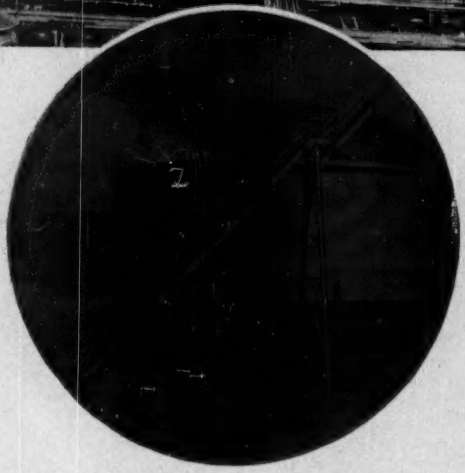

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